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NORSK GEOLOGISK TIDSSKRIFT 33

THE GRAPTOLITE FAUNA OF THE DICTYONEMA SHALES OF THE OSLO REGION

BY

O. M. B. BULMAN
(Sedgwick Museum, Cambridge, England)

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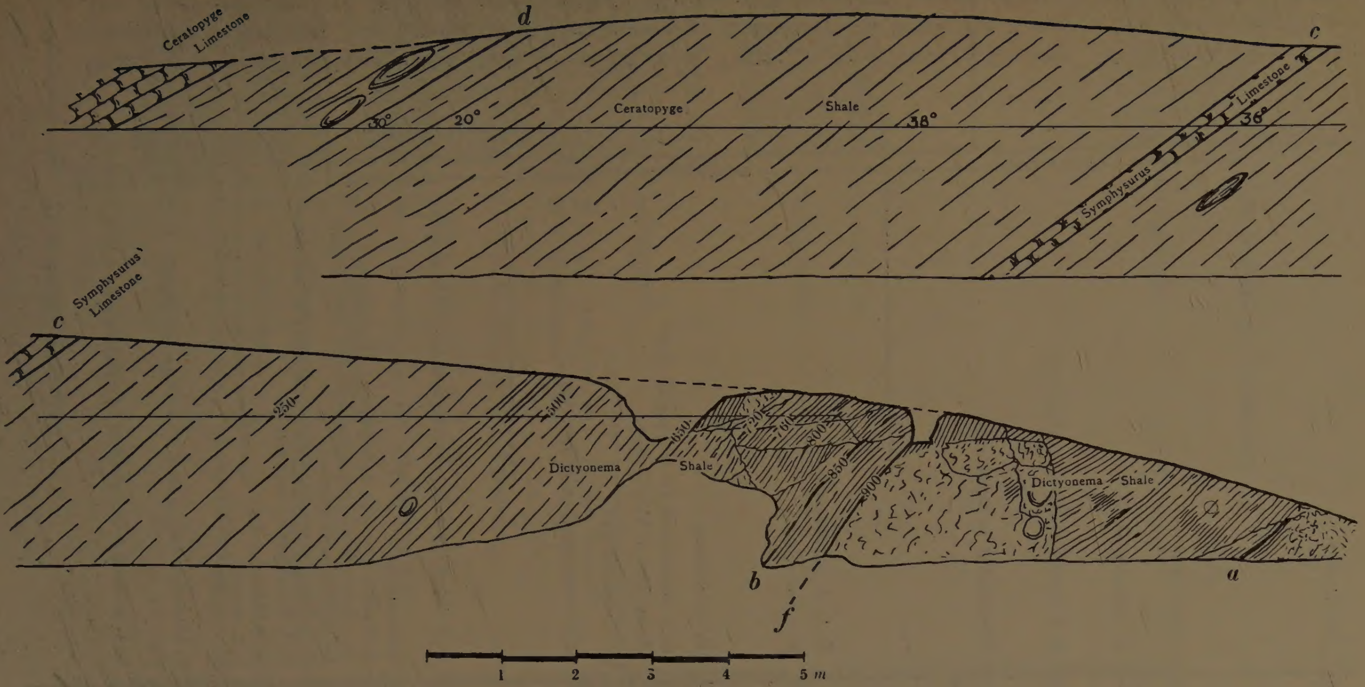
Abstract. This is the first attempt at a complete revision of the graptolite fauna of the Dictyonema Shales (2e) of the Oslo district. Two localities have been selected, Tøyen and Hammersborg; the former provides a practically complete succession, and the latter has furnished a remarkably rich *Anisograptus* fauna in its upper portion. The presence of anisograptids as a characteristic component of the fauna, and the absence (or extreme rarity) of *Clonograptus*, seems to link the Norwegian succession with the Dictyonema Shales of eastern North America. Variation in *Dictyonema flabelliforme* and the stratigraphical value of its varieties are discussed; and the systematic section comprises descriptions of eighteen forms (*Dictyonema* and Anisograptidae) including three new species and three new varieties.

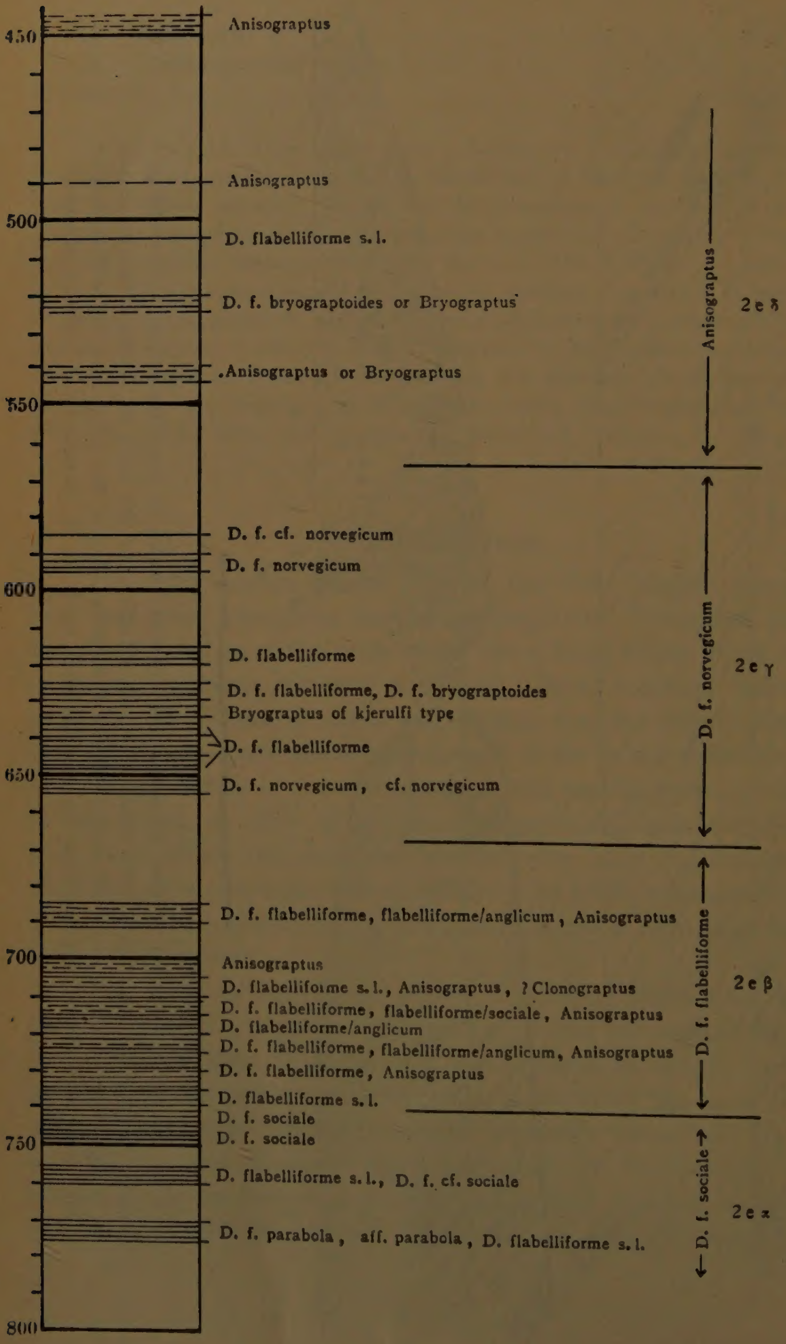
Introduction.

The Dictyonema Shales (2e) of the Oslo Region provide the best and most complete section of graptolitic Tremadoc rocks yet described, and detailed collections have been made from carefully measured sections at four localities. Minor tectonic disturbance undoubtedly occurs in these soft shales, but the effects where they can be checked are never great, and there is no evidence of any serious interference. In consequence, the stratigraphical succession is as certain as that of Scania (the generally accepted European standard) where the sequence has recently been confirmed by the evidence of a borehole (HEDE 1951); it is more extensive than has been described elsewhere in northwest Europe; and the shales are richly fossiliferous.

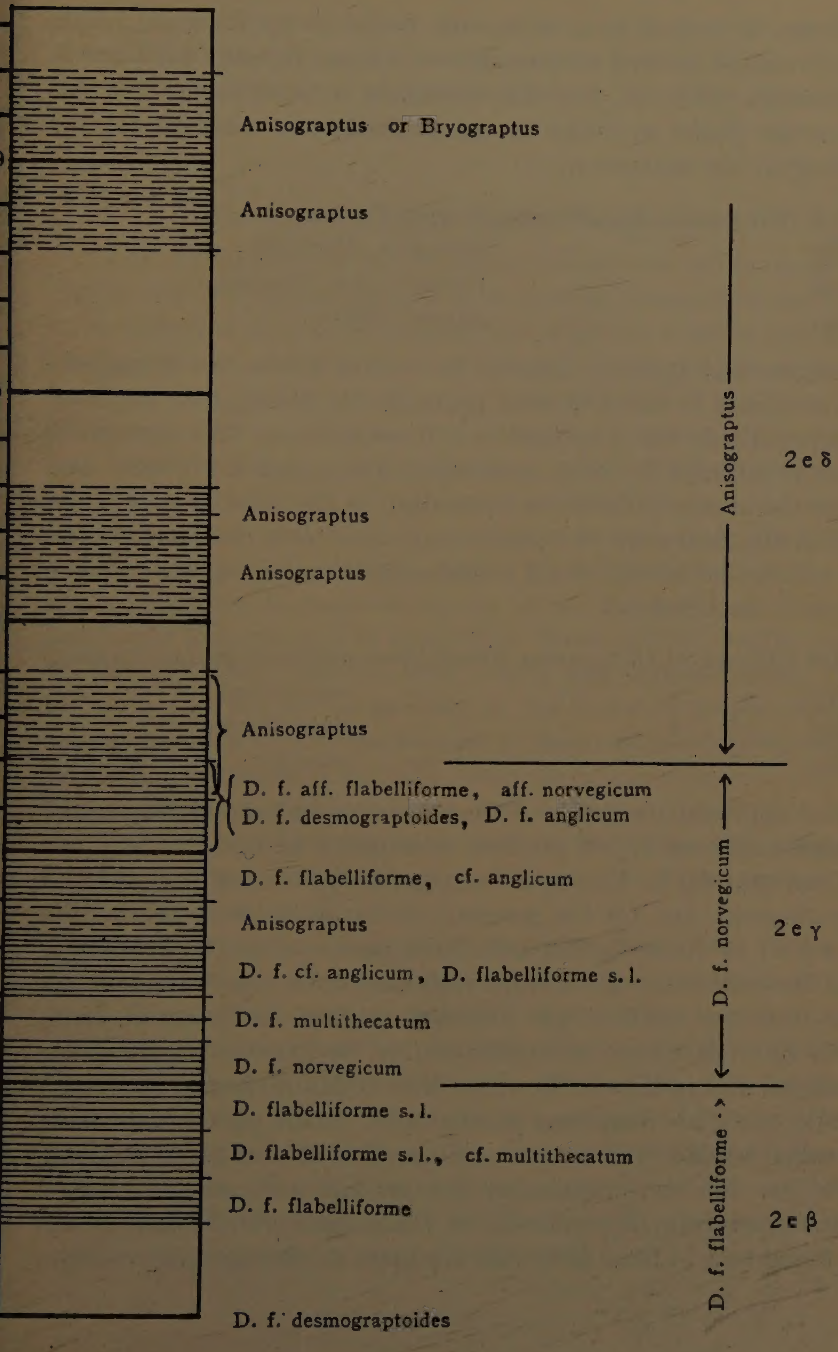
The four sections from which collections have been obtained are: — Vækkerø, Bygdøy Sjøbad, Tøyen and Hammersborg. It has only been possible to work over two of these in detail: Tøyen (collected by L. STØRMER in 1940) which is probably the most complete, and is that from which KJERULF originally described his variety *norvegicum;* and Hammersborg (collected by O. REKDAL in 1922) which is now no longer accessible and is that which has yielded the richest anisograptid fauna. The profile at Hammersborg is shown



Text-fig. 1. Profile of the section from the Dictyonema Shales to the Ceratopyge Limestone at Hammersborg, after an unpublished drawing by O. Rekdal, to the scale of 1:100. Measurements are recorded from the base of the Symphysurus Limestone. Below the fault *f* at 900, the sections is repeated and the fauna has not been described. a, b, c, d, datum lines used by Rekdal.


450
500
550
600
650
700
750
800
Anisograptus
Anisograptus
D. flabelliforme s. l.
D. f. bryograptoides or Bryograptus
Anisograptus or Bryograptus
D. f. cf. norvegicum
D. f. norvegicum
D. flabelliforme
D. f. flabelliforme, D. f. bryograptoides
Bryograptus of kjerulfi type
D. f. flabelliforme
D. f. norvegicum, cf. norvegicum
D. f. flabelliforme, flabelliforme/anglicum, Anisograptus
Anisograptus
D. flabelliforme s. l., Anisograptus, ? Clonograptus
D. f. flabelliforme, flabelliforme/sociale, Anisograptus
D. flabelliforme/anglicum
D. f. flabelliforme, flabelliforme/anglicum, Anisograptus
D. f. flabelliforme, Anisograptus
D. flabelliforme s. l.
D. f. sociale
D. f. sociale
D. flabelliforme s. l., D. f. cf. sociale
D. f. parabola, aff. parabola, D. flabelliforme s. l.
Anisograptus
D. f. norvegicum
D. f. flabelliforme
D. f. sociale
2 e δ
2 e γ
2 e β
2 e α

Text-fig. 2. Section through the Dictyonema Shale at Tøyen, scale 4.9 cm to 1 metre. The Symphysurus Limestone is not exposed, and figures on the left represent distances + x below the Symphysurus Limestone. This is the most complete and least disturbed section. Horizons characterized by anisograptids are indicated by broken lines; *Dictyonema* by continuous lines.


Anisograptus or Bryograptus
Anisograptus
Anisograptus
Anisograptus
Anisograptus
D. f. aff. flabelliforme, aff. norvegicum
D. f. desmograptoides, D. f. anglicum
D. f. flabelliforme, cf. anglicum
Anisograptus
D. f. cf. anglicum, D. flabelliforme s. l.
D. f. multithecatum
D. f. norvegicum
D. flabelliforme s. l.
D. flabelliforme s. l., cf. multithecatum
D. f. flabelliforme
D. f. desmograptoides
Anisograptus
D. f. norvegicum
D. f. flabelliforme
2 e δ
2 e γ
2 e β

Text-fig. 3. Section through the Dictyonema Shale at Hammersborg, scale 6.0 cm to 1 metre. Figures on the left give distances below the Symphysurus Limestone. This section corresponds to the upper part of the Tøyen section and is remarkable for the profusion of anisograptids. *Anisograptus* alone occurs rather sparingly throughout the uppermost 1.5 m of the section (as shown by broken lines) but is abundant at the main *Anisograptus* horizon, 760—790. *Dictyonema* horizons indicated by continuous lines in text-fig. 1 (copied from a drawing prepared by Rekdal), while faunal details of the two sections are summarised in text-figs. 2 and 3.

Størmer (1940, p. 162) has published a short account of the Dictyonema Shales in which he established as a standard for the Oslo Region the succession: —

2eδ *Dictyonema flabelliforme anglica* Bulman
2eγ — — *norvegica* (Kjerulf)
2eβ — — forma *typica* Brøgger
2eα — — *sociale* (Salter)

at Vækkerø and Bygdøy Sjøbad. Neither at Tøyen nor Hammersborg, as shown in the following pages, is *D. flabelliforme anglicum* well represented; but (especially at Hammersborg) the *norvegicum* horizon is followed by beds containing *Anisograptus*. It may well be that the *anglica* subzone is equivalent to the base, if not to the whole, of the *Anisograptus* horizon; and since both these successions occur within the Oslo district, I would suggest that Størmer's scheme be slightly modified: —

2eδ Subzone of *Dictyonema flabelliforme anglicum* or *Anisograptus*
2eγ — » — — *norvegicum*
2eβ — » — — *flabelliforme*
2eα — » — — *sociale*

The approximate limits of these subdivisions are shown in the Hammersborg and Tøyen profiles, text-figs. 2 and 3.

I am grateful to Professor Størmer for placing all this material at my disposal, and for his generous invitation to visit Oslo at the end of 1951 to study further collections preserved in the Palaeontological Museum there. He and his staff have done everything possible to facilitate my work; I am indebted to Prof. L. Størmer, cand. real. G. Henningsmoen and cand. real. N. Spjeldnæs for discussion and advice, and to Miss L. Monsen, Miss B. Mauritz and cand. real. N. Spjeldnæs for numerous photographs. Other photographs have been taken by Mr. A. Barlow and myself at the Sedgwick Museum, Cambridge. For the preparation of clear and accurate illustrations of meshstructure in the variants of *Dictyonema flabelliforme*, it has been found best to trace in Indian ink upon x4 photographic enlargements on matt paper, which were subsequently bleached and have been reduced (in making the blocks) to magnification x2. To illustrate the general appearance of the rhabdosome, however, photographs still seem most satisfactory.

Variation in Dictyonema flabelliforme.

The variability of *Dictyonema flabelliforme* is so great that hardly any two specimens ever seem exactly comparable and in any large collection of these organisms the range of variation and diverse combination of characters is bewildering. Most workers must have felt hesitation in distinguishing varieties at all, and doubt as to the validity of such varieties as they attempted to define. This situation was recognized long ago by Brøgger, who while separating var. *conferta* (=*sociale*) and *norvegicum* from his *forma typica*, nevertheless wrote (1882, p. 35): »Die verschiedenen Varietäten aus einander zu halten, scheint aber bei der grossen Mannichfaltigkeit des Variirens kaum möglich». In addition to the above, however, other varieties have since been recognized, notably by Hahn in 1912; and in working on the extensive material from Tøyen and Hammersborg, I have reluctantly added to the number in the following pages. But it is clearly desirable to keep the number of these rather arbitrary varieties as small as possible, especially when there is no definite evidence of positive stratigraphical value, and to make considerable use of the qualifications «cf.» and «aff.», or even to employ the designation «*D. flabelliforme* sensu lato». A general review of the position may perhaps be of interest.

Thecal characters have been employed but little in the subdivision of the species, chiefly because of the comparative rarity with which they can be observed, and partly because the thecae do appear in general to be more constant than other features of the rhabdosome. Admittedly there is some variation in number per unit length, but on the whole this seems to be more a geographical feature affecting all varieties of one district or area than a distinction between different varieties. Thecal form varies scarcely at all, but one variety described below (*multithecatum*) has long slender apertural spines in addition to unusually numerous autothecae.

The features most readily observable and therefore most naturally used in the subdivision of the species are (1) mesh characters (determined by regularity, width, direction and closeness of branches and dissepiments) and (2) rhabdosome shape. Neither of these is altogether satisfactory in application, for the appearance of the mesh depends a great deal upon the preservation of delicate dissepiments (and these are liable to destruction and still more to concealment by matrix), and rhabdosome shape requires for its use the preservation of the entire rhabdosome. These conditions are not fulfilled with sufficient regularity to make the use of quantitative methods a very practicable proposition, although the characters themselves would seem ideally suited to such methods.

These two apparently unrelated variables (mesh characters and rhabdosome shape) are in fact linked by a third, namely, frequency of branching, which determines the actual number of stipes in a rhabdosome. A change in shape from narrow- to wide-angled cone must be accompanied by a compensatory increase in the frequency of branching if the mesh character is to remain comparable. If not accompanied by such an increase, it must result in wider spacing of the branches (as seems actually to have occurred in *flabelliforme* and *anglicum* as compared with *sociale*). On the other hand, a marked decrease in the power of branching without change in rhabdosome shape would also result in a more open mesh (as in the aberrant rhabdosome labelled «aff. *flabelliforme*» in pl. 4, fig. 1); and carried further could result in a still narrower rhabdosome even if the branches became further apart (as seems to have occurred in *bryograptoides*). There does seem to be a general tendency towards reduction in the number of branches and the development of greater regularity, resulting in the formation of more-or-less regular *zones* of branching, but this never becomes so regular that the zones can be accurately measured and strictly applied as a varietal character. The use of the same feature, expressed as branch density at successive distances from the sicula, is tempting; but even this has never proved practicable because, like rhabdosome shape, it requires the preservation of complete colonies. We are therefore in practice thrown back upon a *qualitative* study of mesh characters and an estimate (where possible) of rhabdosome shape.

In the above paragraph, I have assumed a transition from *sociale* through *flabelliforme* to *anglicum* and *bryograptoides* for which the stratigraphical evidence is discussed later and is contained in the details of the Tøyen section (text-fig. 2). Granting this, it is of interest to note that change in rhabdosome shape from narrow- to wide-angled cone, and reduction in the frequency of branching are both expressions of the same two trends (change in direction of growth, and stipe reduction) that operate later in the early Graptoloidea.

The characters of the dissepiments themselves are of course independent either of rhabdosome shape or of branching. KOZLOWSKI has stated (1942, p. 42) that dissepiments are mainly composed of cortical substance, and it is to be inferred that they were therefore secreted by that hypothetical outer covering of soft tissue which is believed to have enveloped the graptolite branch. It is consequently probable that they, more than any other feature of the rhabdosome, might reflect variation in external conditions (i.e., they would exhibit what are currently termed phenotypic modifications). It is observable that their density appears to some extent directly related to the density of the branches themselves, suggesting that their development may perhaps be influenced by the proximity of neighbouring branches; and it is quite probable that their function is as much (if not more) to hold branches apart as to hold them together. Thus the high density of dissepiments in *sociale* may be linked with the closeness of stipes in that variety. But the extreme width of dissepiments in, for example, *norvegicum* may perhaps be related to variation in some environmental factor. Were this the case, the stratigraphical value of such a variety would be impaired since it might arise at different times in different regions — i. e,, it could be both local and recurrent. In this connection, the occurrence of a form closely resembling the true *norvegicum* at the low Tøyen horizon referred to on p. 25 is perhaps significant.

Stratigraphical value of the varieties of Dictyonema flabelliforme.

The Scandinavian succession was in the first instance established by BRØGGER (1882) working in the Oslo region, when he recorded *norvegicum* from «a higher level» (p. 36) than his *forma typica* (=*flabelliforme*), and *conferta* (=*sociale*) from «the lower part of the Dictyonema Shales» (pp. 35, 36). WESTERGÅRD (1909) established the zonal succession: —

c. *D. flabelliforme norvegicum* & *Bryograptus kjerulfi*
b. *Clonograptus tenellus* & *Adelograptus hunnebergensis*
a. *Dictyonema flabelliforme flabelliforme*

but he recorded *sociale* from both the upper and lower part of subzone *a* at Pålstorp and Storberg respectively (p. 60).

STUBBLEFIELD & BULMAN (1927) recognized a comparable but incomplete succession in Shropshire, and BULMAN (1927) while describing a new variety, *anglicum*, from the upper part of the *flabelliforme* subzone and beds transitional to *Clonograptus*, considered *sociale* to be restricted to the lower part. The stratigraphical relations of *anglicum* to *norvegicum* remained undecided, but the succession of varieties was generally believed to be: —

norvegicum
  Clonograptus
anglicum
flabelliforme
sociale

Apart from WESTERGÅRD's Pålstorp reference, the only serious exception to this placing of *sociale* is reported from the Dyle Valley in Belgium (LECOMPTE 1948), where a form which appeared to the present writer to be *sociale* occurs in association with trilobites which indicate at least the *Clonograptus tenellus* subzone. HEDE, (1951) in his recent account of the Fågelsång boring, has described a well-defined *sociale* horizon underlying that of *flabelliforme* s. str., though he notes (p. 20) that the variety persists into the basal beds of the overlying (*flabelliforme*) zone where the index fossil itself is rare — i. e., there is a sort of transition series. This would seem to be sufficient to establish the general succession in Scania, but it is very desirable that the Belgian record and that of WESTERGÅRD should be clarified before the occurrence of *sociale* can in itself be confidently accepted as a reliable index of low zonal horizon.

In the Oslo successions, particularly that of Tøyen, the actual ranges of all these varieties show considerable overlap although the horizons of their maximum development agree reasonably well with previous observations. The main exception concerns *anglicum*, which appears to be approximately contemporaneous with *norvegicum*; it even occurs above *norvegicum* at Hammersborg (where the latter is not particularly abundant), while *norvegicum* occurs at two levels above *flabelliforme/anglica* transients at Tøyen. The best of the Oslo *anglicum* material comes from Vækkerø (not described here) where again it overlies *norvegicum*. Comparison with ranges in other countries is somewhat complicated by the extreme rarity, if not complete absence, of *Clonograptus* and *Adelograptus* from the Norwegian succession. It is noteworthy that *flabelliforme flabelliforme* (or a form only doubtfully distinguishable from this) persists to a level even higher than *norvegicum*, and evidently *anglicum* also persists longer here. This point may later be settled by detailed examination of the Vækkerø section.

To summarise, it appears that none of the many varietal forms of *flabelliforme* is universally restricted to a narrow horizon, and furthermore, there will be found throughout the succession many examples which can only be identified as *D. flabelliforme* s. l., or referred with some qualification to described varieties. At the same time, in an assemblage large enough to be representative, it is probable that dominance of *sociale*, *flabelliforme* and even *norvegicum* justifies recognition of these subzones. In most areas, *anglicum* characterises the higher part of the *flabelliforme* subzone; but is has not been recognized in Sweden as yet, while in Norway it persists and may characterise a horizon above *norvegicum*. The *Adelograptus* and *Clonograptus* subzone, where this occurs, interrupts the *Dictyonema* sequence above the *flabelliforme* subzone. It may be added that var. *bryograptoides* seems appropriately characteristic of a high level (*norvegicum* subzone), but there is not sufficient evidence to suggest that the remaining varieties have any particular stratigraphical significance, unless the limited occurrence of the rare *parabola* proves to be characteristic.

Comparison with the graptolitic Tremadoc of other areas.

Three distinctive features emerge from this examination of the Norwegian Dictyonema Shale succession, viz.: the presence of *Aniscgraptus*, here described for the first time from Europe; the extreme rarity, if not absence, of *Clonograptus;* and the persistence of *Dictyonema* itself almost uninterruptedly through these shales.

The presence of anisograptids in the Dictyonema Shales of Oslo raises again the question of the age of the Matane Shales of Quebec, from whence they were first described. These shales were provisionally assigned to a horizon in the lower part of the Upper Tremadoc or the upper part of the Dictyonema Shales (BULMAN 1950) on various grounds; partly features of the *Dictyonema* species and partly the presence of *Triograptus*, till then only known from the Upper Tremadoc, 3aβ, in Norway (MONSEN 1925), where it was likewise associated with early *Didymograptus*. But as then stated (1950, p. 66): «Clearly a fauna of the general aspect of the Matane anisograptid fauna can occur much lower than the Ceratopyge Shales, 3aβ; apparently in the *norvegica* zone of the Dictyonema Shale, 2e». The Tøyen and Hammersborg sections have not only furnished abundant anisograptids in the Dictyonema Shale (associated with *Triograptus* and even ?*Didymograptus*), but the additional variation in *Dictyonema flabelliforme* illustrated by the spined *multithecatum* suggests that the Canadian species could after all be approximately contemporaneous. Nevertheless, it is pertinent to add that neither *D. flabelliforme* itself nor any of its well-recognised varieties occurs in Quebec. If, therefore, the Matane fauna is of Lower Tremadoc (Dictyonema Shale) age, it must be a curiously restricted development. Moreover, though anisograptids occur in the lower parts, the main *Anisograptus* horizon in the Oslo area occurs in and just above the highest *Dictyonema*-bearing shales, and anisograptids persist there after the disappearance of *Dictyonema*.

However, even if the Matane Shales are of later age than the Dictyonema Shales of Norway, the abundance of anisograptids in both regions suggest that possibly we have here evidence of a graptolitic sub-province. The Dictyonema beds of other parts of eastern North America — Cape Breton, New Brunswick, Newfoundland and even New York — are not really well-enough known to establish their relationship to such a province, but it may be noted that anisograptids occur in several of them, and that *C. tenellus* and its variety *callavei*, and *Adelograptus*, have not been recorded from any of them. The Norwegian succession undoubtedly seems to have more affinity with this region than with other parts of northwest Europe.

The persistence of *Dictyonema* almost uninterruptedly through the Norwegian succession also deserves a little further comment. Details recently given by HEDE (1951, pp. 14, 20—28) show that in Scania (Fågelsång) there is a break of over 4 metres without *Dictyonema* between the *flabelliforme* and *norvegicum* levels. The lower *Dictyonema* horizon is remarkably thin (*sociale* and *flabelliforme* together make only 0.60 m) compared with the zone of *Adelograptus hunnebergensis* (and *C. tenellus*) which totals 2.95 m; and even though *flabelliforme* persists into the lowermost 35 cm of this, there is still a gap of 2.60 m of this zone, followed by 1.6 m of Brachiopod Beds (4.2 m altogether) before the reappearance of *Dictyonema* in the form of var. *norvegicum*.

In Britain, there is a similar disappearance of *Dictyonema* soon after the entry of *Clonograptus* and *Adelograptus;* but with the probable exception of cf. *norvegicum* from the Coventry boring (the strati-

NORWAY Oslo	SWEDEN Scania	BRITAIN Shropshire
Symphysurus limestone and shales (3 *a* α)	Ceratopyge shales and limestones	Brachiopod Beds
Main *Anisogr.* horizon		
norvegicum & *anglicum*	*norvegicum*	
	Brachiopod Beds	
flabelliforme with some *Anisogr.* and ? *Clonogr.*	*Adelogr.* and *Clonograptus*	*Clonograptus* and *Adelograptus* Transition Beds with *anglicum*
	flabelliforme	*flabelliforme*
sociale	*sociale*	*sociale*
parabola		

graphical relations of which are a little doubtful), the species does not re-enter the area, and the true *norvegicum* is not represented. Sweden, on the other hand, appears to lack the development of *anglicum* which characterises the upper part of the *flabelliforme* zone in Britain, and beds transitional to *Clonograptus*, and appears in the upper part of the Oslo succession.

In Belgium, *sociale*, *flabelliforme* and *anglicum* (with transients) have all been reported (e. g., Lecompte 1949), but their stratigraphical relations are not very clearly established as yet. Neither *Clonograptus* and *Adelograptus* nor *Anisograptus* has so far been recorded; *Dictyonema* appears to be almost continuous.

Systematic descriptions.

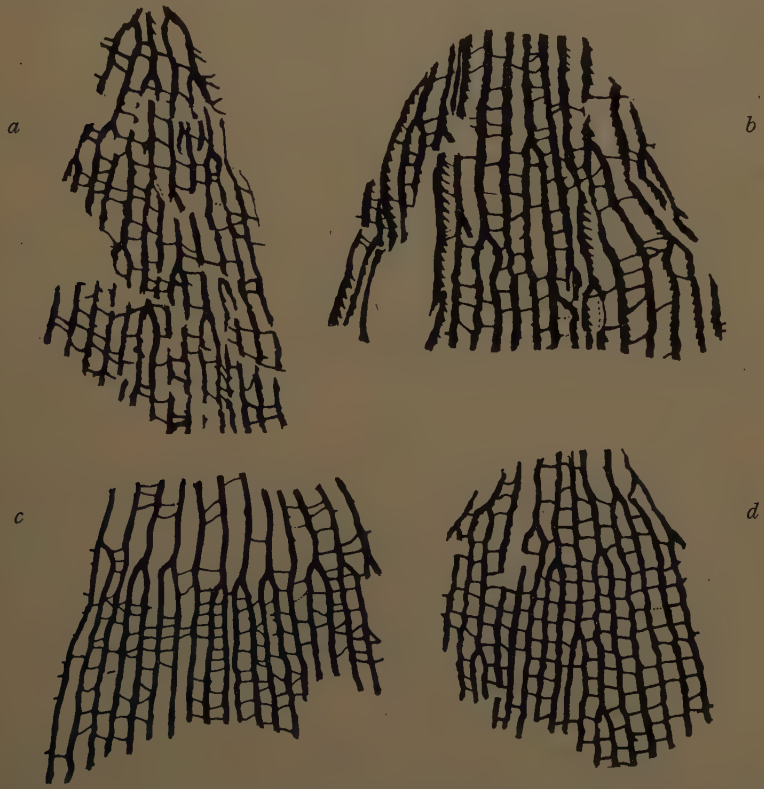
1. *Dictyonema flabelliforme flabelliforme* (Eichwald).

Pl. 2, figs. 1—5; text-fig. 4 a-d.

Gorgonia flabelliformis Eichwald, 1840, p. 207.
Rhabdinopora flabelliformis Eichwald, 1855, p. 435.
Dictyonema Graptolithinum Kjerulf, 1865, p. 1, figs. 4, 5.
Dictyonema flabelliforme Tullberg, 1882, p. 20, pl. III, figs. 1, 2, ?4, (*non* 3).
Dictyograptus flabelliformis forma typica Brøgger, 1882, p. 31, pl. XII, figs. 17, 18.
?*Dictyonema flabelliforme* var. *Acadicum* Matthew, 1891, p. 36.
Dictyonema flabelliforme Ruedemann, 1904 (*pars*), p. 599.
Dictyograptus flabelliformis Moberg & Segerberg, 1906, p. 59, pl. I, fig. 6.
Dictyograptus flabelliformis forma typica Westergård, 1909, p. 57, pl. III, figs. 1—6.
?*Dictyonema flabelliforme* var. *acadica* Hahn, 1912, p. 137, pl. XX.
Dictyograptus flabelliformis Poulsen, 1922, p. 6, fig. 2.
Dictyonema flabelliforme forma typica Bulman, 1927, p. 24, pl. II, figs. 3, 4.
Dictyonema flabelliforme typica Lecompte, 1949, pp. 4 *et seq*.

Diagnosis: Rhabdosome with length/breadth ratio from 1.2:1 to 1.6:1; mesh characteristically regular, composed of slender straight stipes (7—9 in 10 mm) united by slender straight dissepiments (about 7—9 in 10 mm) not appreciably enlarged at their bases, forming more-or-less rectangular meshes; thecae 12—16 in 10 mm.

Description: Probably the most distinctive feature of this form is a certain «open» character of the mesh, which is composed of slender straight stipes, generally a trifle less than 0.5 mm wide, separated by interspaces nearly twice as great, and united by extremely fine and rather infrequent dissepiments. Typically, as noticed apparently by EICHWALD, the mesh is regular and rectangular; but there is considerable range of variation in the number and direction of dissepiments. In some examples these are comparatively close-set (8—10 in 10 mm), regularly spaced and at right angles to the branches, producing a remarkably regular squarish mesh. In other examples, they may be more widely spaced (6—8 in 10 mm), not (so far as can be deter-



Text-fig. 4. *Dictyonema flabelliforme flabelliforme* (EICHWALD). *a*, specimen P. M. O. 62869a from Hammersborg 450 below fault at 900; *b*, KJERULF'S original *Dictyonema Graptolithinum* from Tøyen (cf. pl. 2, fig. 1); *c*, specimen from Baltischport, Esthonia (probably topotype material); *d*, from the Shineton Shales, Cherme's Dingle, near the Wrekin, Shropshire. All figs. x 2.

mined) as the result of injury or damage, and are oblique to the stipes, producing triangular or trapezoidal meshes: in places, two dissepiments may spring from the same point on one branch and diverge strongly. Very regular, square meshes (text-fig. 4d) characterise material from the Shineton Shales (Shropshire); the more irregular and sometimes oblique meshes are represented in topotype material (text-fig. 4c), from Baltischport (Esthonia), the type of KJERULF's *D. Graptolithinum* (text-fig. 4b) from Vækkerø, and are perhaps commoner in the Oslo region generally. It does not seem possible to separate these forms, and appreciable variation may occur in the same rhabdosome.

Rhabdosomes frequently attain a considerable size; thus at Tøyen 730—735 there are specimens 12 cm broad which would probably have had a length of 16 cm or more, and specimens 10—12 cm long occur at several localities and horizons (e.g. pl. 2, fig. 5). From 6 to 8 cm is, however, certainly a more usual length.

Both in rhabdosome shape (length/breadth ratio) and mesh structure (density of branches and dissepiments) there occur forms which serve to connect *flabelliforme* s. str. with *sociale*, *norvegicum* and *anglicum* and can best be identified as transients. There remain also many specimens which, for various reasons, can only be identified as *D. flabelliforme* aff. *flabelliforme*, or even as *D. flabelliforme* sensu lato.

Inwardly-directed thecae are sometimes visible along marginal branches of the rhabdosome in this variety. Indications on the Oslo specimens seem to average 12—13 in 10 mm, which is indeed the number cited by BRØGGER. It is of interest to note in this connection that the Swedish material agrees with the English material in having a higher thecal number, averaging 15—16 in 10 mm (WESTERGÅRD, 1909, p. 58; BULMAN, 1927, p. 25)[1]. MATTHEW, in his var. *acadia*, which is probably synonymous with *flabelliforme*, records 16—17 (1891, p. 37). They generally appear to be sharply denticulate, but unspined, and in compressed specimens are inclined at about 40° to the dorsal wall of the stipe.

STØRMER (1933, 1935) has described and figured some remarkable basal modifications in young rhabdosomes mainly referable to *D. flabelliforme flabelliforme.* The interpretation of these is not absolutely certain, but they are distinct from the root-like fibres and «basal organs» that have been described in *D. flabelliforme* by many authors; for the best of them (1933, text-fig. 1 and pl. 1) is a bladder-like object which involves the basal branches of the rhabdosome and is not merely an enlargement of a thickened nema, and it has morever a firm outline and a smoothly rounded shape. STØRMER interprets it as a floating organ (or pneumatocyst), in which case it might perhaps be better compared with the float of some biserial graptolites than with the central web-structure of certain dichograptids. At this stage we can only state that such an interpretation is quite plausible, but it must be added that there appear to be other specimens (mainly extra-Norwegian) possibly transitional between this and structures that can only be regarded as irregular «root» modifications.

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[1] TULLBERG (1882, p. 20), however, allows the very wide range of 10—15; this is possibly in part owing to the inclusion of other varieties.

Horizons: Tøyen 625—630, 640—645, 685—692, 710—715, 720—725, 730—735, ?755.

Hammersborg ?780—800, 790—800, 800—810, 870—880 (also at various levels below fault at 900, such as *a* = 1350).

From the evidence of these new collections, it appears that *D. flabelliforme flabelliforme* may persist to a higher level than was previously realised, occurring with and even above *norvegicum.* Some of this higher material seems indistinguishable from that found at lower horizons, but some specimens (e. g., pl. 4, fig. 2) show an unusually rapid initial bifurcation and consequently a rounded proximal end. If this could be definitely established as characteristic, it might be worth separating such forms as a distinct variety; only one or two are known, however, and these are provisionally identified as aff. *flabelliforme.*

2. *Dictyonema flabelliforme anglicum* BULMAN.

Pl. 4, figs. 3 & 5; text-fig. 5*a*.

Dictyonema flabelliforme var. *anglica* BULMAN, 1927, p. 28, pl. 2, figs. 5—8.
?*Dictyonema flabelliforme* var. *anglica* RUEDEMANN, 1930, p. 308, figs. 1, 2.
?*Dictyonema flabelliforme* var. *anglica* RUEDEMANN, 1947, p. 160, pl. 2, figs. 3—5, pl. 4, fig. 25.
Dictyonema flabelliforme var. *anglica* LECOMPTE, 1949, pp. 4 *et seq.*

Diagnosis: Rhabdosome characterised by its broadly conical form (length/breadth ratio 1.2:1 to 1:1) and open mesh; stipes 6—8 in 10 mm, 0.3—0.4 mm wide and separated by interspaces which may be three or even nearly four times as great; dissepiments 6—10 in 10 mm; thecae 14—16 in 10 mm, acutely denticulate or with short spines.

Remarks: Specimens definitely referable to this form are not common, but occur in the upper part of the Hammersborg section (pl. 4, fig. 3) and at Vækkerø (pl. 4, fig. 5). They are characterised by their slender, widely separated branches and open mesh, combined with the broadly conical rhabdosome form. Examples identifiable as *flabelliforme/anglicum* transients, or as cf. *anglicum* (pl. 4, fig. 4) occur more commonly both in the Tøyen and Hammersborg sections (Tøyen 720—725, 688—692, and Hammersborg 820—830, 800—810).

Imperfectly preserved specimens are liable to be confused with *bryograptoides* and *multithecatum;* the former should be distinguishable by their very infrequent bifurcation and acute rhabdosome form, and their exceptionally sparse dissepiments; the latter are mainly distinguishable by their sparse dissepiments and thecal characters.

Horizon: Hammersborg 780—800; also Vækkerø.

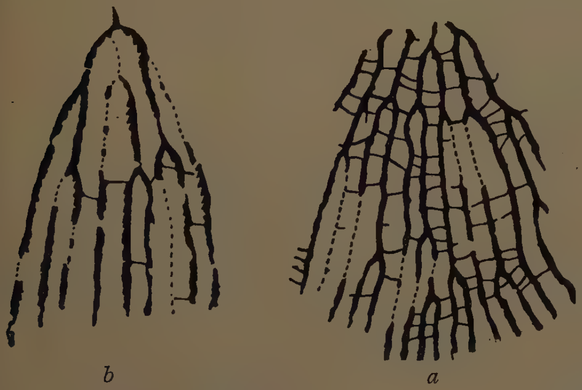
3. *Dictyonema flabelliforme bryograptoides* var. nov.

Pl. 4, figs. 6, 7; text-fig. 5 *b, c*.

Diagnosis: Rhabdosome small, with length/breadth ratio 1.4:1 or 1.5:1, branching at infrequent intervals (approximately 3½, 9 and 15 mm); branches straight, slender (less than 0.5 mm), separated by interspaces two to three times as great, 6—8 in 10 mm; dissepiments so infrequent that their number has little significance; thecae ?12—13 in 10 mm, acutely denticulate but not spined; stolothecae and bithecae observed.

Description: The rhabdosome does not seem to exceed 2½ cm in length, nor to have more than 18—20 terminal branches (9—10 visible when compressed); and has a high length/breadth ratio. The stipes are slender, widely separated, and connected by a few dissepiments in the middle and distal portions.

The variety is distinguished from young *anglicum* by its narrow cone and far more infrequent dissepiments; it more closely resembles the form referred to cf. *multithecatum*, but its even less frequent branching and much lower thecal number should serve to discriminate between them. It is, in fact, a morphological intermediate between *D. flabelliforme* and a *Bryograptus;* and it is possible that the specimen figured by WESTERGÅRD (1909, pl. 5, fig. 7) as *Bryograptus kjerulfi* is referable to this variety. It occurs high in the succession, associated with *norvegicum*, which is about the horizon where bryograptids first make their appearance.



Text-fig. 5. *a*, *Dictyonema flabelliforme anglicum* BULMAN, Vækkerø, P.M.O. 114 (cf. pl. 4, fig. 5).
b, *c*, *Dictyonema flabelliforme bryograptoides* nov., Tøyen 625, P.M.O. 61977; *b*, holotype (cf. pl. 4, fig. 6). All figs. x 2.

Holotype: P.M.O. 61977 (the rhabdosome shown on the right in fig. 6, pl. 4, and in text-fig. 5b).
Horizon: Tøyen 625, 625—630, ? 520—525.

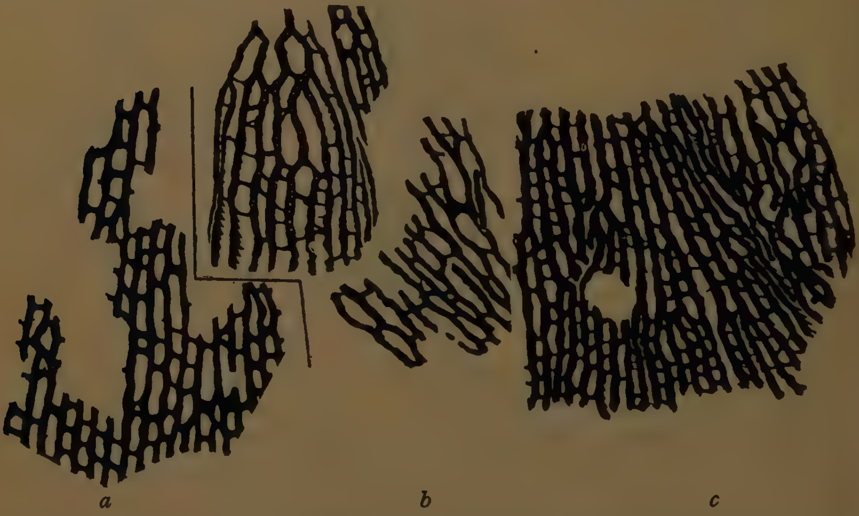
4. *Dictyonema flabelliforme desmograptoides* HAHN.

Pl. 5, figs. 1—4; text-fig. 6 a-c.

Dictyonema flabelliforme var. *desmograptoidea* HAHN, 1912, p. 139, pl. XX.

Diagnosis: Rhabdosome form uncertain; stipes 8—12 in 10 mm, somewhat undulating and occasionally appearing to anastomose; dissepiments irregular, often widely spaced to produce elongate meshes, sometimes close-set (10—11 in 10 mm), not infrequently thickened, and generally expanded at their bases; thecae ?15—16 in 10 mm.

Remarks: HAHN's original description is very brief, and the variety rests upon a number of rather vague characters not at all easy to define; it has not been recognized hitherto outside New Brunswick, but there seems little doubt that Professor STØRMER's MS identification of the variety among the Oslo material is correct.



Text-fig. 6. *Dictyonema flabelliforme desmograpoides* HAHN. *a*, Hammersborg 780—800, P.M.O. 62683 (cf. pl. 5, fig. 1); *b*, unknown locality (?Eiker), P.M.O. 236 (cf. pl. 5, fig. 4); *c*, Eiker, P.M.O. 65672 (cf. pl. 5, fig. 2). All figs. x 2.

The form of the complete rhabdosome is uncertain, most of the material being torn and broken; but there is some indication that it flared out distally from an initially narrow cone like the hypothetical *acadia/conferta* transient figured by HAHN on his plate XX (1912). There is one such specimen among the Navy Island material in the Sedgwick Museum, and several in the Oslo material, one of which (from an unknown locality, possibly Eiker) is shown in fig. 3, pl. 5.

Most characteristic specimens show a slight sinuosity of the branches, and elongate rectangular or ovoid meshes formed by thickened dissepiments greatly expanded at their bases and by very rare anastomosis. The stipes are 8—10 in in 10 mm, separated by interspaces slightly greater than the stipe witdth. There is, however, an element of irregularity both in spacing of dissepiments and in the branching itself; stipes often end blindly and are replaced by the division of adjacent stipes, as shown in text-fig. 6c. Here the stipes tend to be more numerous, and are often separated by interspaces actually less than the stipe width, while dissepiments are finer and more numerous.

HAHN reports that sometimes an old stage of *acadica* (? = *flabelliforme* s.str.) shows the characters of *desmograptoides*, but I am inclined to think that he is mistaking a general irregularity, with premature termination of various branches (which may occur exceptionally in most varieties), for the true *desmograptoides* structure. Certainly *desmograptoides* shows such terminal irregularities rather freqently, but in the Oslo material at least, the true *desmograptoides* characters as described in the preceding paragraph are generally most pronounced in the proximal rather than the distal end of the rhabdosome.

Where the dissepiments are more numerous and the elongate mesh is not so well developed, the variety may show considerable resemblance to *flabelliforme* cf. *norvegicum*.

Horizon: Not known for certain at Tøyen; Hammersborg 780—800 (rare) and just below fault at 900; also Eiker, and an unknown locality (old collections).

5. *Dictyonema flabelliforme multithecatum* var. nov.

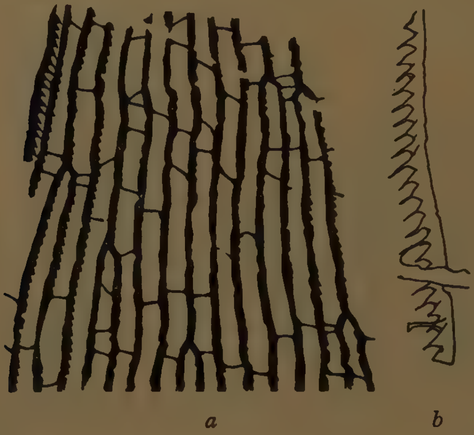
Pl. 5, fig. 5; text-fig. 7a, b.

Diagnosis: Rhabdosome shape and proportions uncertain; mesh very open, with straight slender stipes separated by interspaces 2 to 2½ times the stipe width, 6—7 in 10 mm, connected by sparse dissepiments 2—5? in 10 mm; autothecae 18—20 in 10 mm, provided with straight apertural spines ½ mm or more in length.

Description: The form of the entire rhabdosome is not known, but it appears to have been much as in *flabelliforme* s.str.; some immature specimens (e. g., pl. 5, fig. 6) referred to this variety with reserve suggest a length/breadth ratio of about 1.4:1.

The stipes are straight and parallel, slender (not more than

0.5 mm wide) and separated by interspaces from two- to two-and-a-half times as wide. Branching in the mature part of the colony is infrequent and irregular; at the proximal end, it seems to be somewhat between *flabelliforme* s.str. and *bryograptoides.* Dissepiments are very sparsely developed and in some places absent altogether over a length of a centimetre or more between adjacent pairs of stipes; in other places, two may occur in the space of one mm. So far as can be determined, their absence is primary and not due to damage or to poor preservation. Nevertheless the stipes remain parallel and the colony shows little tendency to disruption such as commonly affects rhabdosomes of the Canadian *D. lapworthi*, where dissepiments are also sparsely developed.



Text-fig. 7. *Dictyonema flabelliforme multithecatum* nov. *a*, Hammersborg 835, P.M.O. 62415, x 2. *b*, thecae showing apertural spines, Hammersborg 835, P.M.O. 62412 (holotype, counterpart of P.M.O. 62415), x 4. (cf. pl. 5, fig. 5).

Apart from this looseness of the mesh, the most distinctive feature of this rare variety are the close-set thecae (numbering 18—20 in 10 mm) and their stiff slender apertural spines. The former is all the more notable because as previously remarked most of the Norwegian varieties seem to differ from their Swedish and English counterparts in having rather fewer than the normal number of thecae.

The spined character of the thecae raises the question whether the autothecae of other varieties of *D. flabelliforme* were similarly spined, their denticulate appearance being due to defective preservation. Re-examination of the best available material from various localities leads me to believe that, while the thecae of other varieties may have been very acutely denticulate, they did not carry the acicular spines that characterise *multithecatum*.

Holotype: P.M.O. 62412; P.M.O. 62415 (represented in text-fig. 7a) is the counterpart.

Horizon: Hammersborg 835 (loose); immature forms referred to cf. *multithecatum* occur at Hammersborg 860—870.

Remarks: A comparable if not identical variety apparently occurs at Baltischport, Esthonia. Most of the Baltischport material is referable to *flabelliforme flabelliforme*, but one specimen (A22651) in the Sedgwick Museum collections shows numerous thecae (18—20 in 10mm) with conspicuous apertural spines, rather shorter (0.25 mm) than those of Hammerborg, and sparse and erratic dissepiments.

6. *Dictyonema flabelliforme norvegicum* (Kjerulf).

Pl. 3, figs. 1—3, ?5; text-fig. 8a-d, ?e

Dictyonema norvegicum Kjerulf, 1865, p. 1, figs. 1 *a*, *b*, *non* figs. 2, 3.
Dictyograptus flabelliformis mut. *norvegica* Brøgger, 1882, p. 36 (no figs.).
Dictyograptus norvegicus Moberg & Segerberg, 1906, p. 60, pl. 1, fig. 7.
Dictyograptus flabelliformis var. *norvegica* Westergård, 1909, p. 60, pl. III, figs. 8, 9.
?*Dictyonema flabelliforme* var. *norvegica* Hahn, 1912, p. 139, pl. XX.

Diagnosis: Stipes connected by thick dissepiments, comparable in thickness to the branches themselves, expanded at their bases to produce rounded meshes.

Description: The shape of the rhabdosome and the proximal end are practically unknown, and the variety is almost invariably represented by irregular fragments, often of considerable size[1]. There is some indication (e. g., pl. 3, fig. 2) that the length/breadth ratio was around 1:1.

The mesh structure of the typical variety is unmistakable. Stipes number 9—10 (rarely 10—11) in 10 mm, are 0.5—0.6 mm wide, and are separated by interspaces of about the same dimension. They are connected by broad dissepiments nearly as wide as, and rarely a little wider than, the branches themselves; and these are expanded at their bases to produce oval or rounded meshes. Dissepiments number about 8 in 10 mm. Plate 3, fig. 1 is typical; so too are text-figs. 8*a* and *b*, and MOBERG & SEGERBERG's fig. 7 or WESTERGÅRD's fig. 8. There is, however, considerable variation in mesh structure and one common variant, almost as characteristic as the above, results from much finer and more numerous dissepiments, up to 12—14 in 10 mm. These are inseparable, for the two commonly occur together in the same rhabdosome, and the second type may affect the dissepiments between two or three stipes only, adjacent

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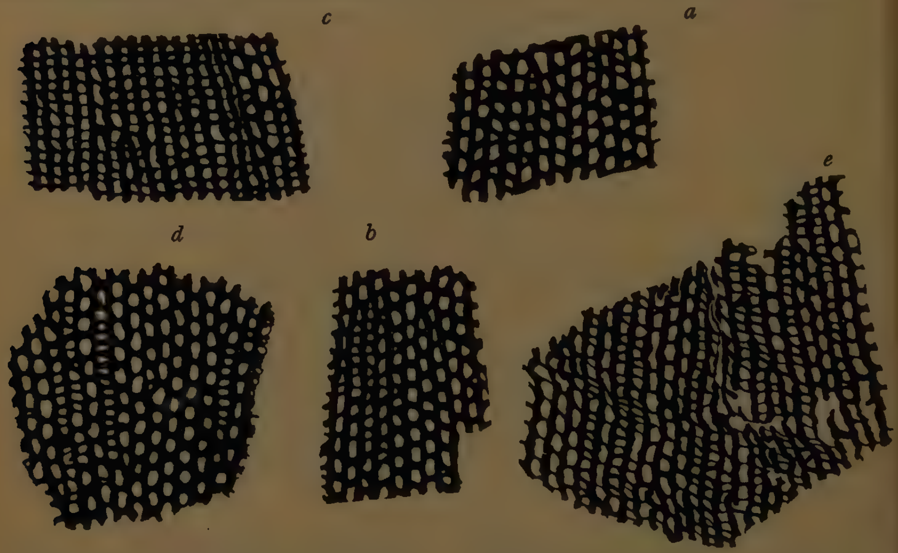
[1] Westergård (1909, p. 60) refers to one piece 11.5 cm long and 13 cm broad, but fragments of 4 or 5 cm are more usual.



Text-fig. 8. *Dictyonema flabelliforme norvegicum* (KJERULF). *a*, *b*, typical coarse mesh with broad dissepiments, Tøyen 590—595; P.M.O. 62000 (cf. pl. 3, fig. 1); *c*, close mesh with fine dissepiments, with patches of coarse mesh on right, Tøyen 650; P. M.O. 61936 (cf. pl. 3, fig. 3); *d*, contrasting areas cf coarse and fine mesh, Bygdøy Sjøbad S. 605 (old collections); *e*, specimen from low level (Tøyen 750) with comparable coarse and fine mesh, P.M.O. 61913 (cf. pl. 3, fig. 4). All figs. x 2.

parts of the rhabdosome being composed of the coarse round-meshed type described above (e. g., pl. 3, fig. 1 and text-figs. 8*c* and *d*).

Thecae were unknown to previous authors, but a marginal branch on one rhabdosome (P.M.O. 61998, Tøyen 590—595) in this collection affords definite evidence of thecae numbering 12 in 10 mm; they are acutely denticulate, the denticles possibly drawn out into short spines, but preservation is not sufficiently good to determine this with certainty.

Type data: KJERULF's original material (1865) came from Tøyen, but has not been identified in the Paleontological Museum Collection.

Horizons: Tøyen 590—595, 650. Hammersborg 840—850.

Remarks: In addition, there are many forms which I refer to this variety with some reserve. Mostly (e. g., pl. 3, fig. 5) these recall the material described as cf. *norvegicum* from the Shineton Shales of the Coventry boring (BULMAN, 1928, p. 29 and 1927, pl. ii, figs. 9, 10). The dissepiments are irregular in spacing, being in places as few as 6, or as many as 10—11, in 10 mm; they are rarely as thick as the stipes, nor are they so conspicuously expanded at their bases as in the typical variety. Such forms seem clearly related to *norvegicum*, perhaps as transients between that variety and *flabelliforme* s.str; they occur both above (Hammersborg 780—800) and below (Tøyen 650—655) the true *norvegicum*. I regard *norvegicum* as a somewhat unstable variety, and would restrict the name to those examples which agree with the material from Tøyen 590—595 and 650 described above; for the remainder, the names cf. *norvegicum* and aff. *norvegicum* may be used.

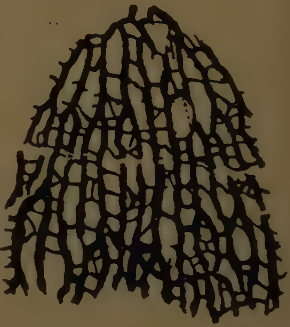
Finally, there is the interesting specimen shown in pl. 3, fig. 4 and text-fig. 8*e*. At a first glance, this would be accepted as a normal *norvegicum*, though the dissepiments are perhaps somewhat more numerous than even in the fine meshed type. It comes, however, from a low level in the Tøyen section (750) where it is associated with *flabelliforme* s. l. and *sociale*, and it seems to represent a development of *norvegicum* characters in some *sociale* stock (see p. 9).

7. *Dictyonema flabelliforme parabola* var. nov.

Pl. 1, figs. 3—5; text-fig. 9.

Diagnosis: Rhabdosome with rounded «shoulders» and more cr less parabolic outline, developed from probably four initial branches; length/breadth ratio varying with age, but approximately 1.2 : 1 to 1.4 : 1 in mature rhabdosomes; stipes 8—10 in 10 mm, separated by interspaces about twice as wide ; dissepiments extremely irregular in spacing and direction, usually slender, somewhat expanded at their bases; thecae ? 13—14 in 10 mm.

Description: One of the most distinctive features of this variety is the rounded proximal end and very rapid initial branching, which is reminiscent of *D. cristatum* of Canada. It is probable that the rhabdosome originates in four primary branches; these divide rapidly at first, but form no significant zones of branching.



Text-fig. 9. *Dictyonema flabelliforme parabola* nov. Counterpart of holotype (pl. 1, fig. 3), Tøyen 770—775, P. M. O. 61773, x 2.

The mesh has typically a rather «loose» and highly irregular appearance; the stipes themselves lack the sub-parallel regularity characteristic of most *D. flabelliforme* varieties, and are instead often slightly flexuous. They not infrequently end blindly and are replaced by the division of an adjacent stipe. They are slender, 0.5 mm wide, separated by interspaces often twice as broad as the stipes and are united by very irregularly developed dissepiments. A few of these have been observed which are actually longitudinal in direction, connecting adjacent dissepiments and they are very variable both in spacing and direction; those shown in pl. 1, fig. 3 (and text-fig. 9) are considered typical, but forms with closer dissepiments (e. g., pl. 1, fig. 4) are also referred to this species. Young rhabdosomes with few dissepiments are rather easily distorted and may assume various shapes.

Young rhabdosomes may present some resemblance to *anglicum*, largely because of the broad rhabdosome form and widely-spaced branches, but the rounded proximal end and irregular dissepiments usually afford adequate distinction. They differ from the Canadian *D. cristatum* by their size and altogether coarser mesh. The rounded proximal end should distinguish them from *D. rusticum*, and although they have something of the mesh characters of that species the dissepiments are more irregular and do not show the peculiar «knotted» appearance of *D. rusticum* (BULMAN, 1950).

Holotype: P.M.O. 61772 (pl. 1, fig. 3); P.M.O. 61773 (text-fig. 9) is the counterpart.

Horizon: The type has been selected from Tøyen 770—775, the lowest *Dictyonema*-bearing horizon of the Tøyen section. It occurs here associated with *D. flabelliforme* s. l. and with poorly preserved and mostly juvenile forms which I have referred to *D. flabelliforme* cf. *parabola*. The species also occurs at Nersnes (collected by G. HENNINGSMOEN) 50 cm below *Jujuyaspis;* very fragmentary specimens from 40—50 cm above *Boeckia hirsuta* at Nersnes (which probably represents the same horizon) may similarly be referable to this variety. In view of its early occurrence, it is of some interest to note that it has so little in common with *D. flabelliforme sociale,* other than its initial rapidity of branching.

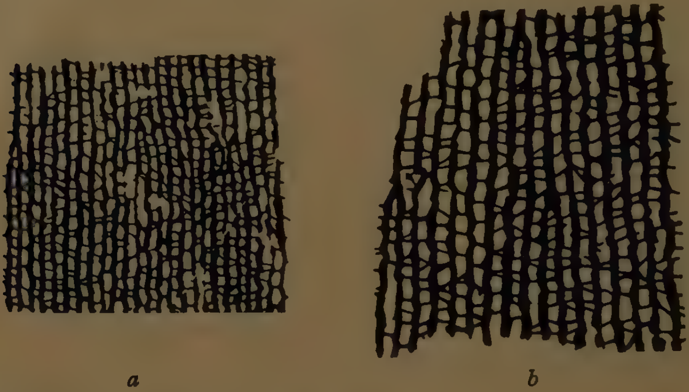
8. *Dictyonema flabelliforme sociale* (SALTER).

Pl. 1, figs. 1, 2; text-fig. 10a

Dictyonema sociale SALTER, 1866, p. 331, pl. iv, figs. 1, 1a-c.
Dictyonema sociale SALTER, 1881, p. 535, pl. iv, figs. 1, 1a-c.
Dictyograptus flabelliformis var. *conferta* LINNARSSON MS, BRØGGER, 1882, pp. 35 & 36 (no figs.).
?*Dictyonema flabelliforme* var. *confertum* MATTHEW, 1891, p. 36.
Dictyograptus flabelliformis var. *conferta* WESTERGÅRD, 1909, p. 59, pl. 3, fig. 7.
?*Dictyonema flabelliforme* var. *conferta* HAHN, 1912, p. 138, pl. XX.
Dictyonema flabelliforme var. *sociale* BULMAN, 1927, p. 26, pl. ii, figs. 1, 2.
Dictyonema flabelliforme var. *sociale* LECOMPTE, 1949, pp. 4 *et seq*.

Diagnosis: The rhabdosome is characterised by its elongate form (length/breadth ratio 1.6 : 1 to 2 : 1 or even slightly more) and fine close mesh — stipes 11—13, dissepiments 13—16, in 10 mm; dissepiments often irregular in direction, but are always very fine in comparison with stipe width.

Remarks: The branching is initially somewhat rapid, though it is difficult to recognise definite zones of branching; but it becomes very infrequent in the more mature portion of the rhabdosome. The stipes are virtually straight, but sometimes present finely irregular, almost zig-zag edges owing to the expansion of dissepimental bases; they are appreciably wider than the interspaces by which they are separated. The dissepiments are mostly straight and at right angles to the stipes, but do show some irregularity both in spacing and direction; they seem to average about 16 in 10 mm in the Tøyen material. There are no definite indications of thecae, which in British forms number 14—15 in 10 mm; WESTERGÅRD (1909, p. 60) cites 16.



Text-fig. 10 *Dictyonema flabelliforme sociale* (Salter) *a*, typical close and fine mesh, Tøyen 745—750, P.M.O. 61816 (cf. pl. 1, fig. 1); *b*, *sociale/flabelliforme* transient, Tøyen 710—715, P.M.O. 61872. Both x 2.

The Tøyen specimens are noteworthy for their size, many rhabdosomes attaining the unusual length (for this variety) of more than 10 cm.

There is no evidence in the Tøyen section of a gradual transition from *sociale* to *flabelliforme* s.str., and the main *sociale* horizon (745—750) is succeeded abruptly by the large well-developed *flabelliforme* of 730—735. Moreover, *sociale/flabelliforme* transients are rare; one of these is illustrated in text-fig. 10*b* from Tøyen 710—715, and they are of course relatively common elsewhere (e. g., Shropshire, Belgium).

Lectotype: The syntypes figured by SALTER in 1866 have now been identified in the collections of the Geological Survey & Museum, and are as follows: fig. 1, 37500; fig. 1a, 10428 (upper part) and

10425 (lower part); fig. 1b, probably 37506; fig. 1c has not yet been traced. G.S.M. 37500 is selected as the lectotype.

Horizon: Tøyen 475—750, ? 755—760.

The variety is not represented at Hammersborg, but occurs at Bygdøy Sjøbad and Eiker, and also (as recorded by BRØGGER) at Vækkerø.

9. *Anisograptus norvegicus* sp. nov.

Pl. 7, figs, 1—5; text-figs. 11a, b.

Diagnosis: Rhabdosome triradiate, horizontal, branching to 4th order to produce 14—16 terminal branches in a mature rhabdosome about 4 cm in diameter stipes 0.3—0.4 mm wide (dorsal view), 0.7—0.9 mm in lateral view measured across the autothecal aperture, composed of autothecae (10—11 in 10 mm), stolothecae and bithecae.

Description: This is a rather variable form in respect of branching. First-order branches range from 1¼ to 3¾ mm in length (generally 1½ to 2½ or 3 mm); they are usually unequal in any given rhabdosome, either one long and two short, or two long and one short (cf. *Anisograptus matanensis*), rarely subequal (all short). Second-order branches average 3½—5 mm, with one recorded instance of 9 mm. Third-order branches are sometimes undivided (up to 2 cm or more in length) or give rise to fourth-order branches at 4½, 5 or even 9—10 mm. Fourth-order branches are all undivided, up to 2 cm in length, with the possible exception of a fifth-order division shown in text-fig. 11*a*.

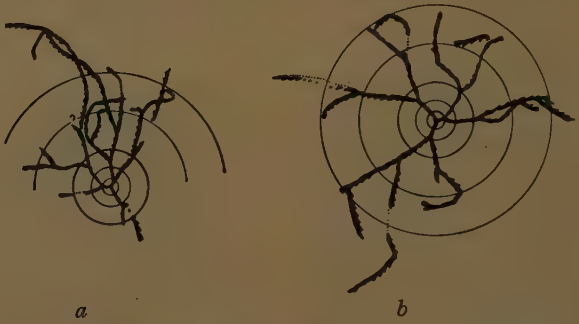
The stipes are slender, 0.3—0.4 mm in dorsal view, 0.7—0.9 mm in lateral view; autothecae number 10—11 or 11 in 10 mm, conspicuous and acutely denticulate in lateral view. Stolothecae and bithecae are present, but not well enough preserved for description.

Holotype: P.M.O. 62224A (pl. 7, fig. 1).

Horizons: Hammersborg 760—790, 740—750, 730—745, ? 720—730. Tøyen ?450.

This is the commonest of the Oslo anisograptids, and mainly characterises a horizon just above the last of the Dictyonemas, though occurring sparingly in the uppermost *Dictyonema* beds. Specimens from the uppermost levels (730—754, pl. 7, fig. 5) differ somewhat from those below in being rather smaller and more delicate, and some examples show evidence of stipe reduction.

Remarks: The species differs from *matanensis* (from which it is possibly only varietally distinct) in its larger size and greater branching capacity and rather fewer thecae; also it does not exhibit that almost diagnostic feature of *matanensis*, namely, that one of the three primary branches is always much shorter than the other two. The terminal branches are longer and more flexuous than in typical *matanensis*.



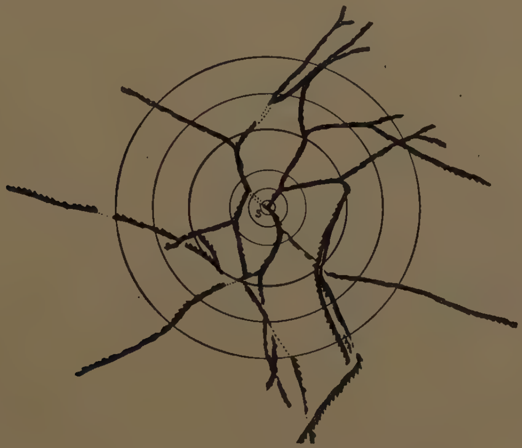
Text-fig. 11. *Anisograptus norvegicus* sp. nov. *a*, Hammersborg 760—790, P.M.O. 62224B (cf. pl. 7, fig. 3); *b*, holotype, same locality and horizon, P.M.O. 62224A (cf. pl. 7, fig. 1). Both x 2. Concentric circles drawn at radii 1, 2½, 5, 10, and 15 mm.

10. *Anisograptus grandis* sp. nov.

Pl. 6, figs. 1—4; text-fig. 12.

Diagnosis: Rhabdosome triradiate, horizontal, branching to 3rd, 4th or rarely 5th order at increasing and comparatively infrequent intervals to produce about 20—25 terminal branches in a full-grown rhabdosome some 6—7 cm in diameter; stipes 0.5—0.6 mm wide in dorsal view, 0.8—1.0 mm in profile measured across the autothecal aperture, composed of autothecae (13 in 10 mm), probably stolothecae and bithecae.

Description: The species is not common, but is distinctive in its large size and infrequent branching. First-order branches are subequal, 3—4 mm in length; second-order branches 5—9 mm (mostly 7—8 mm); some third-order branches are 3—3½ cm long and undivided, others divide at 8—12 mm; of the resulting fourth-order branches, most are 3—3½ cm long and undivided, but a few divide at about 1 cm to produce short fifth-order branches. The branches diverge at a considerable angle (usually about 70°) and though not infrequently displaced, they give an impression of rigidity more like *matanensis* than *flexuosus*.



Text-fig. 12. *Anisograptus grandis* sp. nov. Counterpart of the holotype (pl. 6, fig. 1), Hammersborg 760—790, P.M.O. 62222 x 2. Concentric circles drawn at radii 1, 2½, 5, 10, 15 and 20 mm.

Autothecae number 12—13 (usually 13)in 10 mm; they are denticulate, but seem rather less acutely so than either *matanensis* or *flexuosus*. Stolothecae and bithecae are almost certainly present, but not well preserved.

Holotype: P.M.O. 62222 (pl. 6, fig. 1); P.M.O. 62221, text-fig 12, is the counterpart.

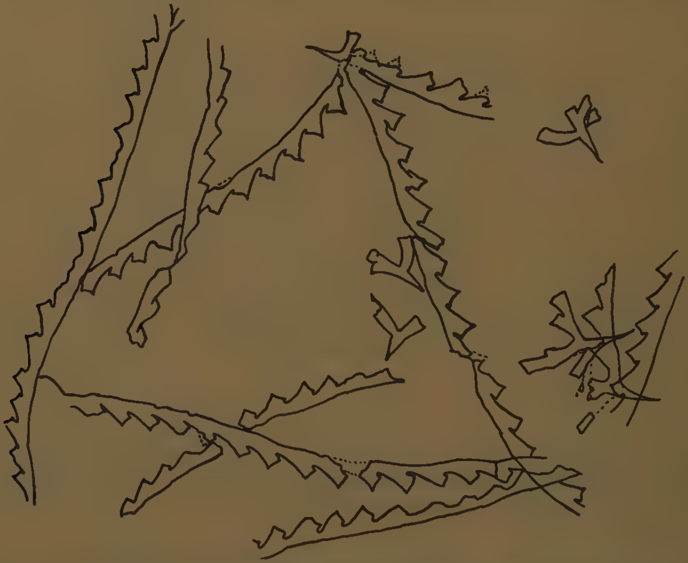
Horizon: Hammersborg 760—790. Tøyen ?450.

Remarks: The species is distinguished from *matanensis* by its greater size and greater capacity for branching, and by its three sub-equal first-order branches. From *flexuosus* it is distinguished by its more «open» proximal end (the three first-order branches are here about 3 mm in length) and the greater length of all orders of branches. Circles are drawn in text-fig. 12 at the same intervals as those used in describing the Canadian forms (BULMAN, 1950) to facilitate comparison.

11. *Anisograptus isolatus* sp. nov.

Pl. 8, fig. 3, ?2; text-fig. 13.

Diagnosis: Form of the complete rhabdosome unknown, apparently triradiate and infrequently branching; stipes flexuous, 0.9—1.0 mm wide in profile measured across the autothecal aperture; autothecae 9—10 in 10 mm, with isolate apertural region, bluntly denticulate; stolothecae and bithecae unknown.



Text-fig. 13. *Anisograptus isolatus* sp. nov. Holotype, Tøyen 700—705, P.M.O. 61876, x 4. (cf. pl. 8, fig. 3).

Description: The species is known only in a fragmentary condition, though sometimes (e.g., pl. 8, fig. 3) matted fragments almost cover an entire bedding plane. It is impossible to make out the complete rhabdosome form, or even to be positive that it is an *Anisograptus*, but more than one example gives the impression that three branches diverge from the sicula, one of which divides almost immediately. Subsequent branching is very infrequent, and branch fragments can be traced from 10 to 20 mm or more without any trace of division; rare dichotomy is, however, probable.

The distinctive feature is the character of the autothecae, which are tubular and distinctly isolate distally. They number 9 or 9—10 in 10 mm; the ventral wall is gently concave and the apertural margin is also slightly concave, so that though the thecal tubes are truncated almost at right angles by the apertural margin, the aperture is slightly denticulate in profile view. The state of preservation of all available material does not permit any observations concerning the presence or absence of bithecae and stolothecae.

Holotype: P.M.O. 61876 (Pl. 8, fig. 3).

Horizons: Tøyen 700—705, 705—710. Hammersborg 780—800, ?740—750.

Remarks: The flexuous branches and infrequent bifurcation give a superficial resemblace to *Anisogr. retroflexus* (BRØGGER) and *Adelogr. hunnebergensis* (MOBERG). but the character of the autothecae is quite distinctive. It should, however, be noted that in poorly preserved material, or when the stipes are not preserved in true profile, this may be difficult to determine.

12. *Anisograptus ruedemanni* BULMAN.

Pl. 6, fig. 5.

Anisograptus ruedemanni BULMAN, 1941, pp. 111, 112, figs. 4a-e.

Remarks: The species was originally described from the *norvegicum* zone of the Dictyonema Shales at Vækkerø; the specimen shown here (pl. 6, fig. 5) comes from a horizon (810—810) just above *norvegicum* at Hammersborg. The three declined primary branches are considerably longer ($6\frac{1}{2}$-7 mm) than was recorded for *ruedemanni*, but details of the range in variation of this feature were not included in my 1941 description; re-examination of all the Vækkerø material preserved at Cambridge shows that primary branches may occasionally attain a length of 7 mm. The other dimensions and general habit of the Hammersborg specimen agree well with *A. ruedemanni*.

Holotype: Sedgwick Museum A 10066*a*. Vækkerø.

Horizon: Hammersborg 810—820.

13. *Anisograptus* spp.

Unidentifiable anisograptid remains occur at many horizons both at Tøyen and Hammersborg, often so abundantly as to cover an entire bedding-plane with a tangled mat of broken fragments; that shown in fig. 1, pl. 8, is fairly typical. It is possible that many of these are identical with or near to *A. norvegicus*, but the fragments are too small to admit identification, there is some evidence that a somewhat smaller species is also present.

Horizons: Tøyen 725, 710—715, 705—710, 688—692, 490—450. Hammersborg 810—820, 790—800, 780—800, 650—670.

14. *Bryograptus kjerulfi* LAPWORTH.

Graptolithus tenuis KJERULF, 1865, pp. 1 & 3, fig. 6a, A & B (*non* c)
Bryograptus kjerulfi LAPWORTH, 1880, p. 164, pl. 5, figs. 22a, b.
Bryograptus kjerulfi BRØGGER, 1882, p. 37, pl. XII, figs. 20, 20a.
Bryograptus kjerulfi MOBERG & SEGERBERG, 1906, p. 61, pl. 1, fig. 14.
Bryograptus kjerulfi WESTERGÅRD, 1909, p. 66, pl. V, figs. 8, ?7, 9.

Remarks: Fragments probably referable to *B. kjerulfi* occur in the upper part of the Tøyen section; but they are far from common, and what appear at first sight to be bryograptids often prove on closer inspection to be immature and fragmentary *Dictyonema*. The species was originally described by KJERULF and BRØGGER from the Vækkerø section, where it may be relatively abundant, but to judge from the Tøyen and Hammersborg sections it is by no means a characteristic zonal index.

Horizons: Tøyen 630—635, 625, ?520—525.

15. *Bryograptus* cf. *ramosus* BRØGGER.

Pl. 4, fig. 9.

Remarks: The specimens here referred with reserve to *Bryograptus ramosus* are fragmentary, but they come from a comparable horizon (about 6 m above the Symphysurus Limestone — actually somewhat higher than the topotypes) and agree well in all determinable features. As remarked elsewhere (BULMAN, 1941, p. 106) it seems probable that there were three primary branches and that the species is correctly referred to *Bryograptus*.

Horizon: Hammersborg d + 20 (see text-fig. 1).

16. ?*Clonograptus tenellus* var. or *Anisograptus* sp.

Pl. 7, figs. 6, 7.

Remarks: The difficulty of distinguishing generically between

Anisograptus and *Clonograptus* rhabdosomes in the absence of a well-defined sicula is very real, and has been commented upon elsewhere several times; with only incomplete rhabdosomes, the difficulty is still greater. There is, however, something about the appearance of the fragments shown on pl. 7, figs. 6 & 7 (which occur on one of the bedding-planes covered with a mat of broken anisograptids) which causes me to suspect that these may be fragments of a *Clonograptus*. The branching is rather too regular for a typical anisograptid; there is a sense of greater rigidity, perhaps because all branches are preserved in dorsal view and there is no visible trace of thecae; and there is a slight but distinctive curvature to the branches, which at bifurcation are slightly more U-shaped than the acute V-shape of typical anisograptids. These points amount to little more than an impression, and the material occurs at a horizon (Tøyen 705—710) slightly lower than *Clonograptus* might be expected to characterise (say around 670—680). If the fragments belong to a *Clonograptus*, they are perhaps nearer to var. *callavei* than any other described variety, but they probably represent a distinct form; if they are anisograptid, they are certainly distinct from anything described above, but the material is really too fragmentary for diagnosis.

Horizon: Tøyen 705—710.

17. *Triograptus* sp.

Pl. 6, fig. 6.

Remarks: The genus is represented by several specimens, but none is sufficiently well-preserved for specific description. All apparently belong to the same species, and in the best of them (shown on pl. 6, fig. 6) the stipes are about 1 cm in length (the longest is 11 mm) and straight; they are 0.35 mm wide at origin, and 0.7 mm measured across thecal apertures in the mature portion of the stipe. The thecae number 14—15 in 10 mm distally and are gently inclined. As none of the stipes is quite in true profile, the maximum width is certainly slightly greater than that quoted above, and the true inclination probably near 30—35°. The presence of bithecae is not certain, but there are indications of stolothecae.

Judging from its straight branches, this species seems nearer

T. canadensis than *T. osloensis* of 3aβ, but the thecae are more numerous than in either of those.

Horizons: Hammersborg 770—780, 760—790.

18. ?*Didymograptus* sp.

Pl. 5, figs. 7—9.

Remarks: Numerous examples of what may be a *Didymograptus* occur in the main *Anisograptus* horizon of Hammersborg. It is possible that they are simply young stages of an *Anisograptus* (probably *A. grandis*), but none show any trace of a third primary stipe and a reference to *Didymograptus* is possible. The sicula is slender, 2.2 mm long and 0.5 mm wide at the aperture. From this arise apparently two branches, which in no specimens exceed a few millimetres in length. They are initially declined, but rapidly become horizontal; they are 0.4 mm wide at origin, and attain an almost uniform width of 0.9 mm measured across the thecal apertures. Thecae occur at the rate of 12—13 in 10 mm and there is no trace of bithecae or stolothecae.

The specimens differ from others described from the Tremadocian by the initially declined rhabdosome, and should the generic reference be well founded, they certainly represent a new species.

Horizon: Hammersborg 760—790.

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Manuscript received March 28. 1953.

PLATES 1–8

All figures x 1½; untouched photographs except where otherwise stated,

P.M.O. = Paleontological Museum, Oslo.

PLATE 1.

Dictyonema flabelliforme sociale (Salter).

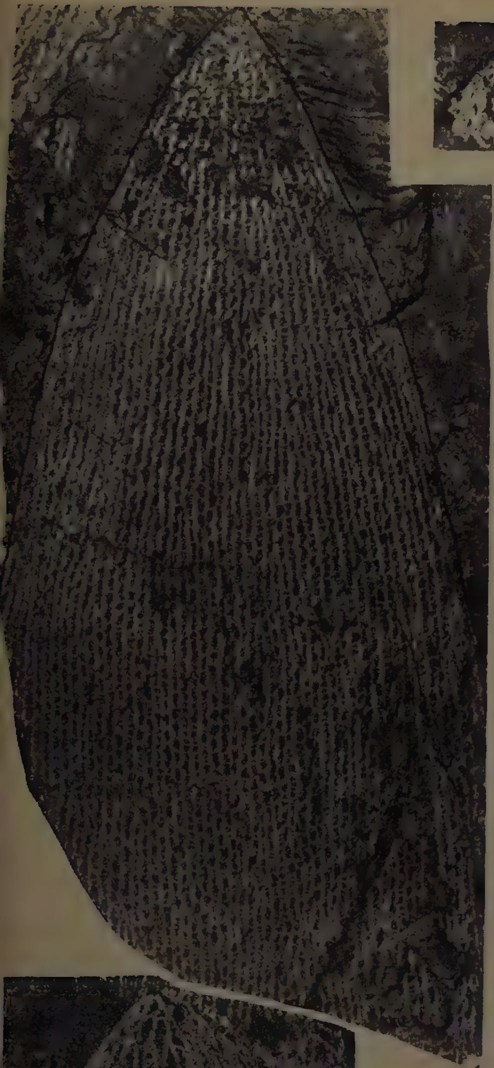
Fig. 1. Typical large rhabdosome; Tøyen 745—750; P.M.O. 61816.
Fig. 2. Smaller and narrower rhabdosome from the same locality and horizon. P.M.O. 61814.

Dictyonema flabelliforme parabola var. nov.

Fig. 3. Holotype; Tøyen 770—775; P.M.O. 61772. (counterpart of specimen shown in text-fig. 9).
Fig. 4. 50 cm below *Jujuyaspis* at Nersnes; P.M.O. 66407.
Fig. 5. Same locality and horizon; unnumbered specimen with P.M.O. 66403.
Figs. 6, 7. *Dictyonema flabelliforme* cf. *parabola.* Immature rhabdosomes with root-like threads from the apex of the sicula. Both on the counterpart of P.M.O. 61776, Tøyen 770—775.

Figs. 5, 6, 7 slightly retouched.

PLATE 1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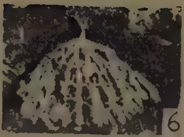
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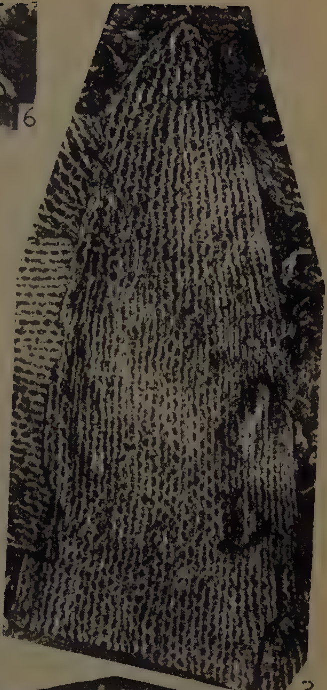
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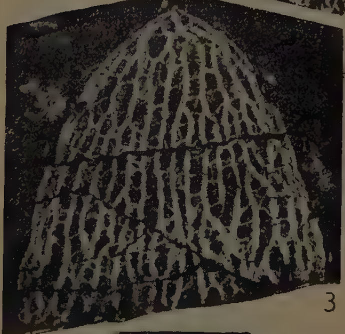
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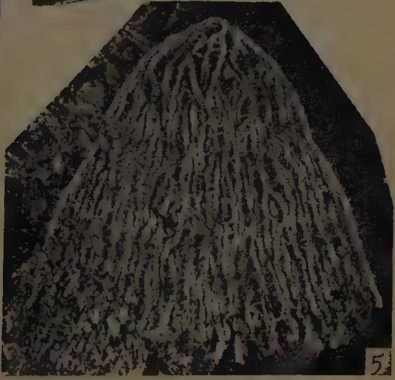
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PLATE 2.

Dictyonema flabelliforme flabelliforme (Eichwald).

Fig. 1. The original of Kjerulf's *Dictyonema Graptolithinum* (1865, fig. 4a) from Vækkerø.

Fig. 2. Another part of the same specimen giving an indication of the size of the rhabdosome.

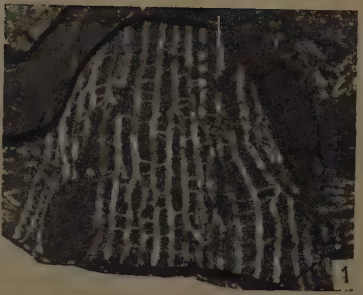
Fig. 3. Almost complete rhabsome showing typical shape and mesh characters Tøyen 710—715; P.M.O 61866.

Fig. 4. Somewhat similar rhabdosome from Hammersborg 790—800; P.M.O 62441.

Fig. 5. A portion of one of the large rhabdosomes from Tøyen 625—630 P.M.O. 61980b. The photograph includes about one-half of the distal end

Figs. 1—4 very slightly retouched.

PLATE 2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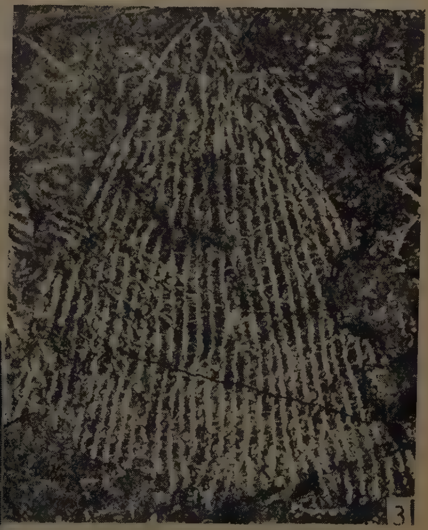
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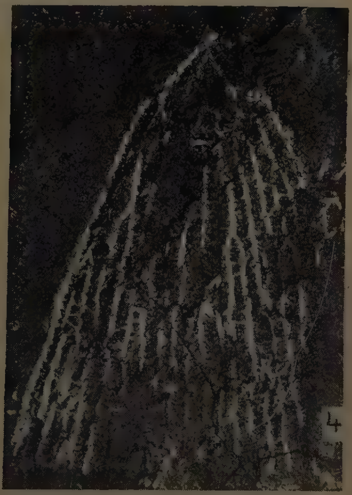
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PLATE 3.

Dictyonema flabelliforme norvegicum (Kjerulf).

Fig. 1. Portions of two rhabdosomes showing, especially top left, the characteristic mesh characters. Tøyen 590—595; P.M.O. 62000.

Fig. 2. Almost complete rhabdosome giving indication of low length/breadth ratio. Hammersborg 840—850; P.M.O. 62450.

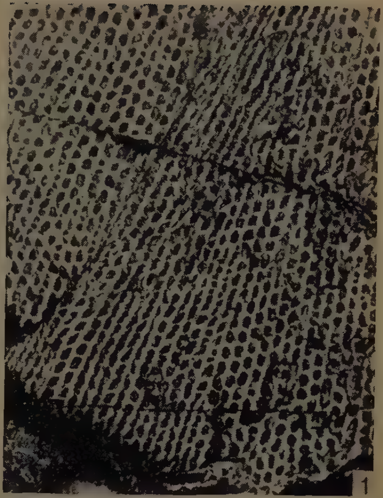
Fig. 3. Distal portion of specimen showing fine, close dissepiments on same rhabdosome as more widely-spaced, thick ones. Tøyen 650; P.M.O. 61936.

Fig. 4. Specimen from low level (Tøyen 750) associated with *D. flabelliforme* s. l. and *sociale*, but showing the characters of true *norvegicum* (cf. fig. 3). P.M.O. 61913.

Fig. 5. *D. flabelliforme* cf. *norvegicum*. Typical of specimens so named in this paper. Tøyen 650—655; P.M.O. 61932.

Fig. 2 slightly retouched.

PLATE 3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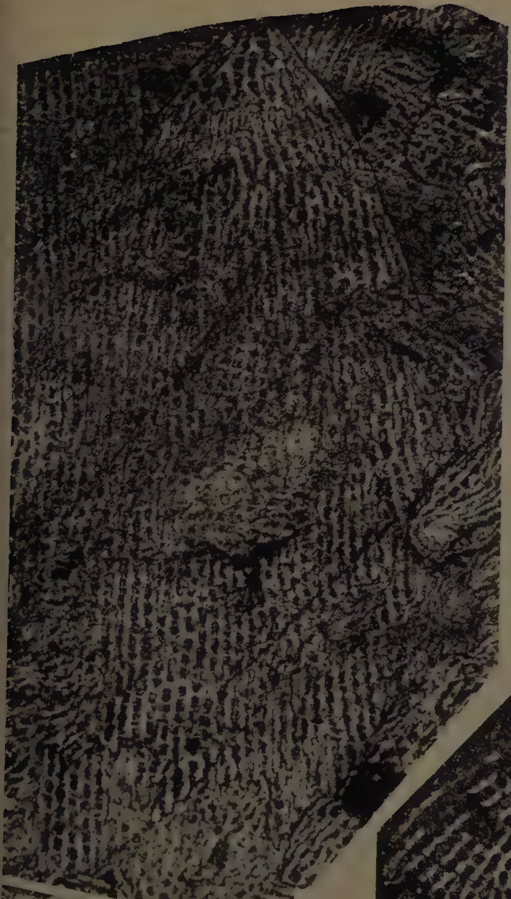
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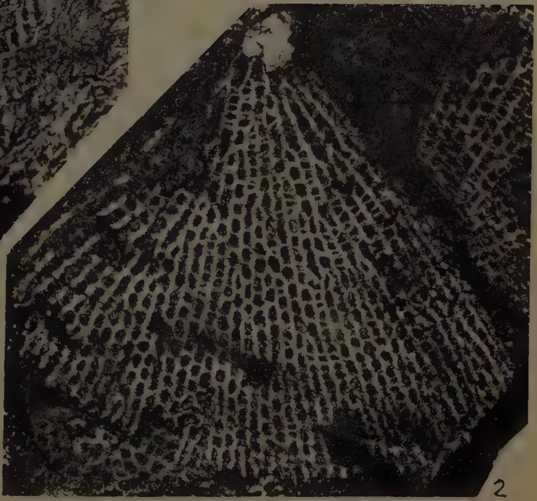
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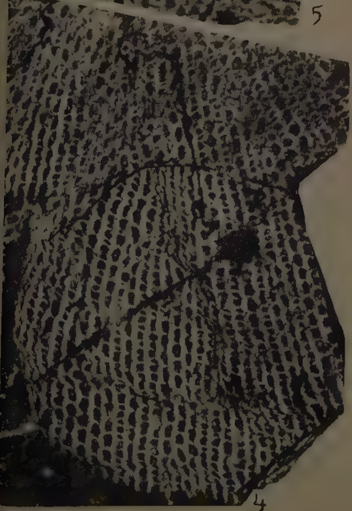
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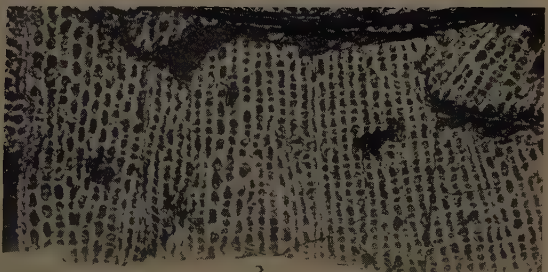
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PLATE 4.

Dictyonema flabelliforme aff. *flabelliforme* (EICHWALD).

Fig. 1. Specimen combining the rhabdosome shape of *sociale* with the mesh characters of *flabelliforme* s. str. (see p. 8); the two sides of the rhabdosome are pressed together and cannot be clearly distinguished. Slemmestad; P.M.O. 143.

Fig. 2. Specimen from high level, above *norvegicum*, showing rapid initial bifurcation. Hammersborg 780—800; P.M.O. 62648.

Dictyonema flabelliforme anglicum BULMAN.

Fig. 3. Typical mesh characters and low length/breadth ratio. Hammersborg 780—800; P.M.O. 62669.

Fig. 4. *D. flabelliforme* cf. *anglicum*. Hammersborg 820—830; P.M.O. 62395.

Fig. 5. Typical well-preserved rhabdosome of *D. flabelliforme anglicum*; the two sides of the rhabdosome are both visible and for clarity, that at the back has been partially blocked-out. Vækkerø, P.M.O. 114.

Dictyonema flabelliforme bryograptoides var. nov.

Fig. 6. The more complete rhabdosome on the right is the holotype. Tøyen 625; P.M.O. 61977.

Fig. 7. Tøyen 625—630; P.M.O. 61969.

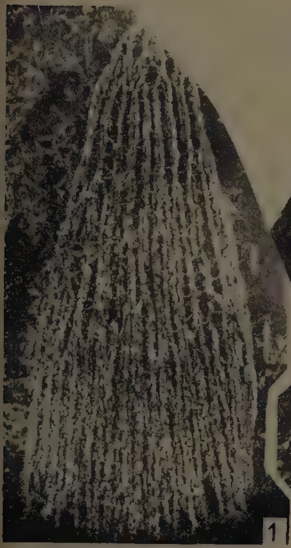
Fig. 8. *D. flabelliforme* cf. *bryograptoides*. Probably immature rhabdosome with somewhat lower length/breadth ratio. Hammersborg 820—830; P.M. P.M.O. 62402.

Bryograptus cf. *ramosus* BRØGGER.

Fig. 9. Fragmentary rhabdosomes from the Ceratopyge Shale, Hammersborg d+20; P.M.O. 62184.

Figs. 1, 5, somewhat retouched.

PLATE 4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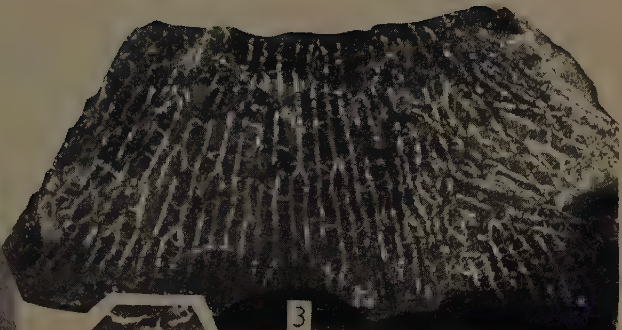
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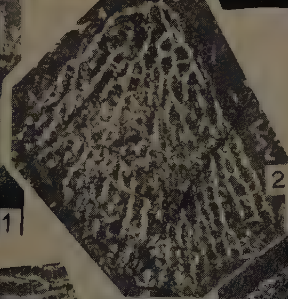
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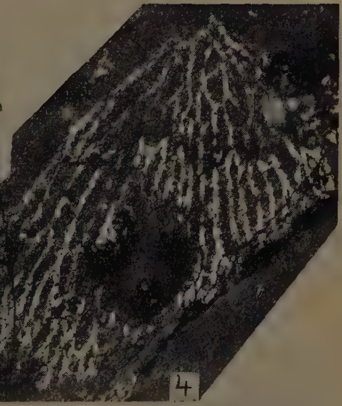
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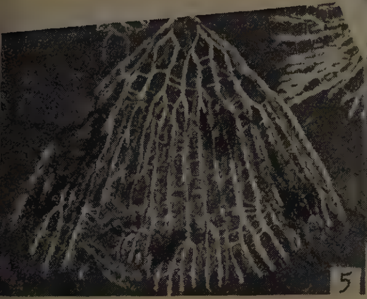
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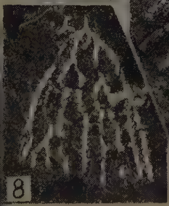
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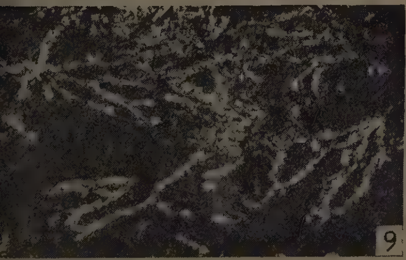
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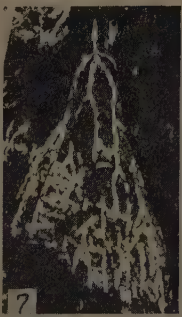
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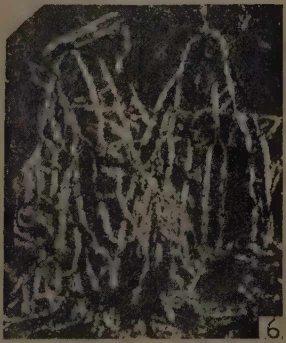
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PLATE 5.

Dictyonema flabelliforme desmograptoides HAHN.

Fig. 1. Fragmentary rhabdosomes showing irregular, rather coarse mesh characters. Hammersborg 780—800; P.M.O. 62683.

Fig. 2. More nearly complete rhabdosome; Eiker; P.M.O. 65672.

Fig. 3. Specimen showing form of proximal end of rhabdosome. Unknown locality, possibly Eiker; P.M.O. 236.

Fig. 4. Other fragments on same piece of shale as fig. 3, showing typically irregular proximal mesh.

Dictyonema flabelliforme multithecatum var. nov.

Fig. 5. Portion of holotype showing sparse dissepiments and long apertural spines. Hammersborg 835; P.M.O. 62412.

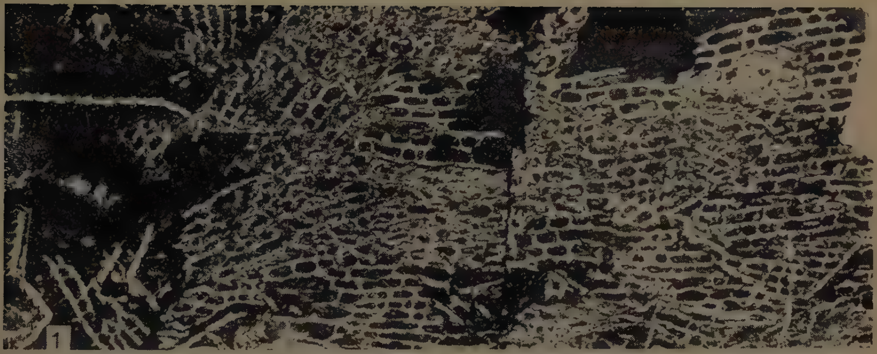
Fig. 6. *D. flabelliforme* cf. *multithecatum*. Proximal end, apertural spines not visible. Hammersborg 860—870; P.M.O. 62897.

?*Didymograptus* sp.

Figs. 7—9. Three examples from the main *Anisograptus* horizon, Hammersborg 760—790; P.M.O. 62222.

Figs. 5—9 slightly retouched.

PLATE 5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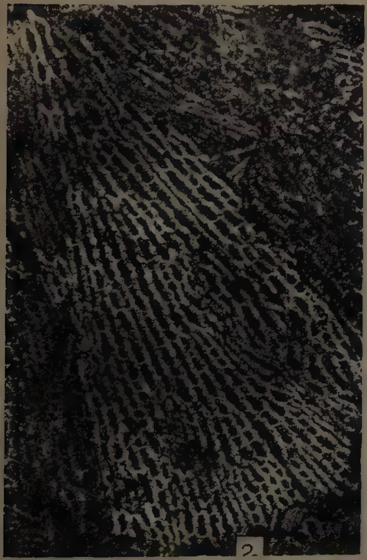
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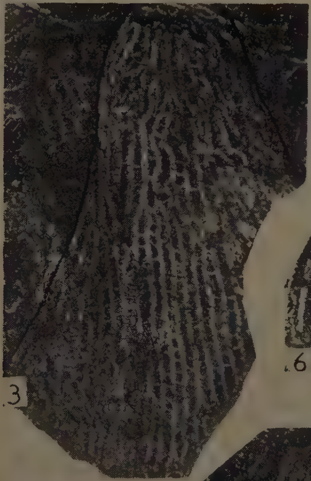
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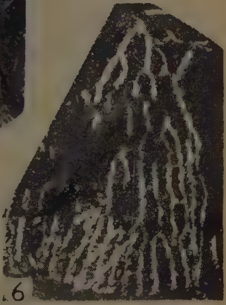
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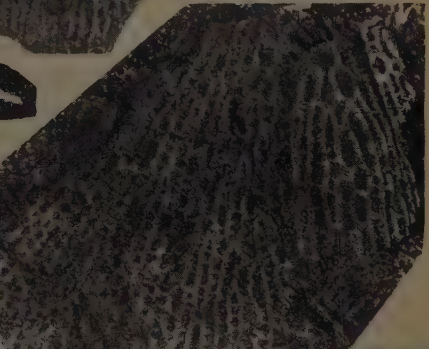
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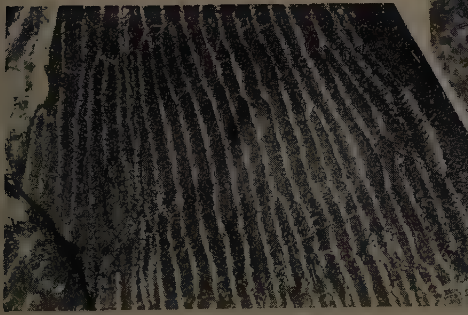
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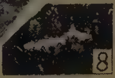
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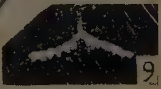
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PLATE 6.

Anisograptus grandis sp. nov.

Fig. 1. Holotype, and counterpart of specimen shown in text-fig. 12. Hammersborg 760—790; P.M.O. 62221 .

Fig. 2. Two less well-preserved and probably immature rhabdosomes. Hammersborg 760—790; P.M.O. 62255.

Fig. 3. Two early growth stages. Hammersborg 780—790; P.M.O. 62479.

Fig. 4. Another similar example. Hammersborg 780—790; P.M.O. 62971.

Anisograptus ruedemanni BULMAN.

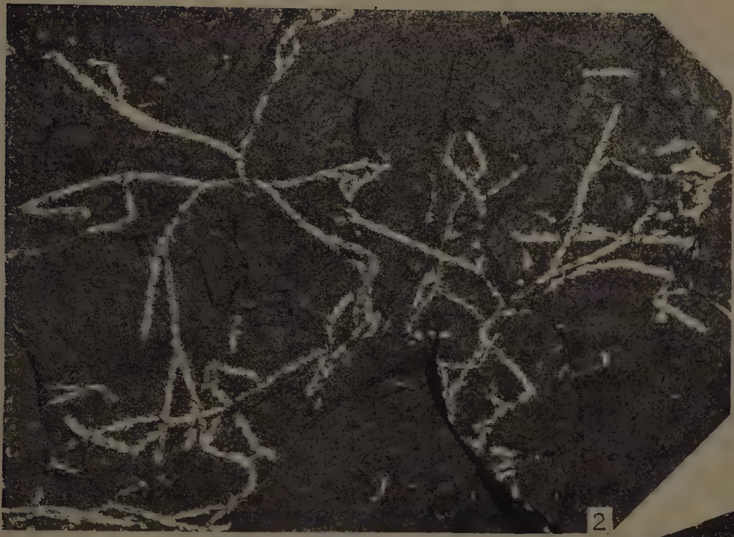
Fig. 5. Hammersborg 810—820: P.M.O. 62430.

Triograptus sp.

Fig. 6. Typical rhabdosome from the main *Anisograptus* horizon, Hammersborg 760—790; P.M.O. 62222.

Fig. 6 slightly retouched.

PLATE 6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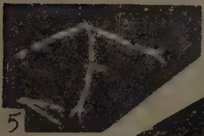
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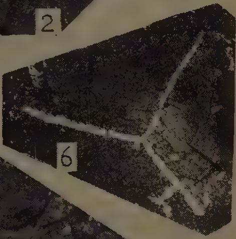
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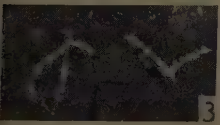
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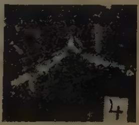
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PLATE 7.

Anisograptus norvegicus sp. nov.

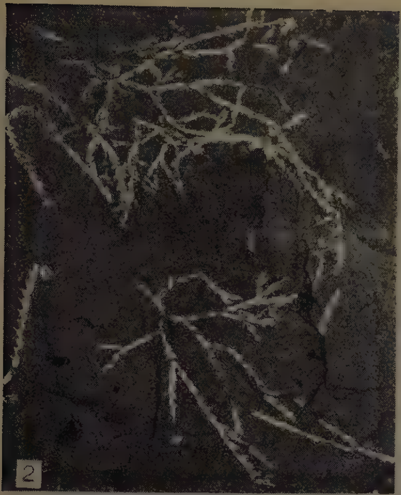
Fig. 1. Holotype, Hammersborg 760—790; P.M.O. 62224A.
Fig. 2. Typical but less well-preserved rhabdosomes. Hammersborg 760—790; P.M.O. 62253.
Fig. 3. Another characteristic rhabdosome. Hammersborg 760—790; P.M.O. 62224B.
Fig. 4. Examples from a slightly higher level. Hammersborg 740—750; P.M.O. 62230.
Fig. 5. Specimens from the uppermost level, Hammersborg 730—745; P.M.O. 62151.

?*Clonograptus tenellus* var. or *Anisograptus* sp.

Figs. 6, 7. Various examples from a bedding-plane covered with a tangled mat of broken anisograptids. Tøyen 705—710; P.M.O. 61875.

Figs. 1, 3, 6 and 7 retouched.

PLATE 7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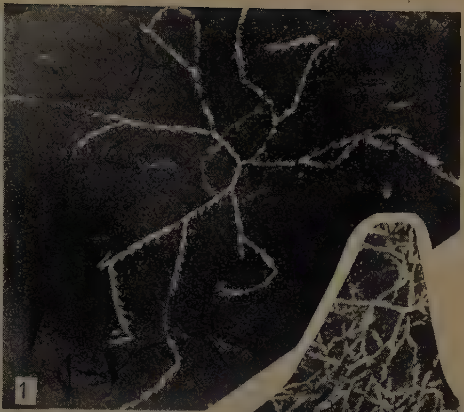
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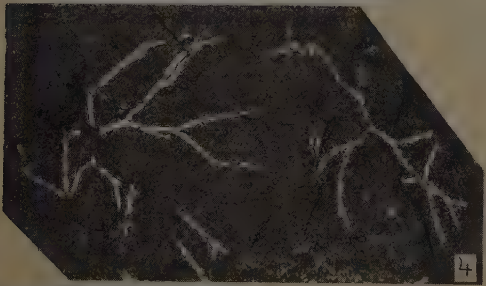
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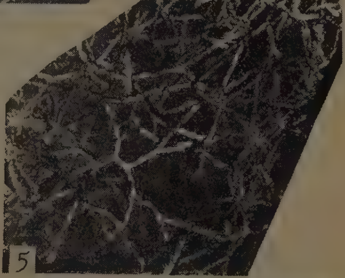
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PLATE 8.

Anisograptus sp.

Fig. 1. Indeterminate anisograptid remains showing characteristic mode of occurrence on various bedding-planes both in the Tøyen and Hammersborg sections. Tøyen 688—692; P.M.O. 61895.

Anisograptus isolatus sp. nov.

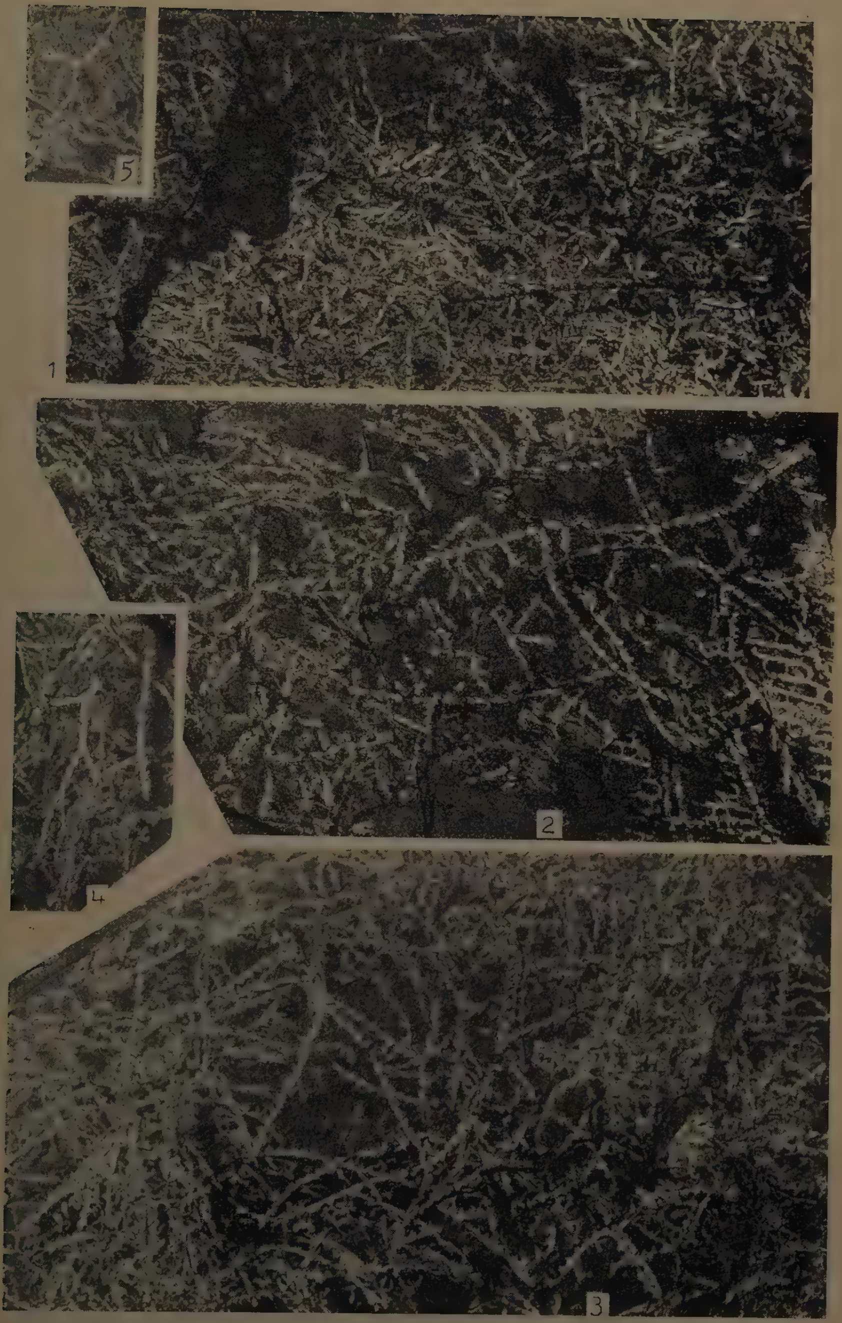
Fig. 2. Specimens probably referable to this species, associated with *D. flabelliforme desmograptoides*. Hammersborg 780—800; P.M.O. 62646.
Fig. 3. Holotype. Tøyen 700—705; P.M.O. 61876.

Anisograptus sp.

Figs. 4, 5. Two indeterminate anisograptid rhabdosomes from a horizon 5 m above the highest *Dictyonema*. Tøyen 450; P.M.O. 62034.

Figs. 4 & 5 retouched.

PLATE 8



LOWER ORDOVICIAN OSTRACODS FROM THE OSLO REGION, NORWAY

BY

GUNNAR HENNINGSMOEN
(Paleontological Museum, University of Oslo)

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Abstract. 11 paleocop ostracods are described from the Lower Ordovician Ceratopyge and Asaphus Series of the Oslo Region in Norway. A chart (p. 63) shows their stratigraphical and geographical distribution. The genus *Nanopsis* is new (type: *Beyrichia nanella* MOBERG & SEGERBERG, 1906), and also the species *Conchoprimitia eos* and the subspecies *C. socialis vulgaris*. Blood canals and muscle marks are described in *Conchoprimitia*.

Introduction.

The Lower Ordovician is here understood to embrace the Ceratopyge Series (2e, 3a) and the Asaphus Series (3b, 3c), corresponding to the Tremadoc and Arenig, respectively, in Great Britain (cf. STØRMER, 1953, p. 45).

Only ostracods belonging to the suborder Paleocopa (Beyrichiacea + Leperditiacea, cf. HENNINGSMOEN, 1953, p. 188) are described in the present paper. Besides these, also a few *Bythocypris*-like ostracods have been met with in the Asaphus Series.

A few Lower Ordovician ostracods have already been reported from the Oslo Region. BRÖGGER (1882) describes *Beyrichia nana* (probably internal moulds of *Tallinnella grewingkii*) and *Isochilina? socialis* (here = *Conchoprimitia socialis socialis* and *C. socialis vulgaris* subsp. n.). ÖPIK (1939) describes *Tetradella grewingkii* (here = *Tallinnella grewingkii*), *Conchoprimitia socialis* (here = *C. socialis vulgaris*) and *C. broeggeri* (here = *C. socialis socialis*). SKJESETH (1952) lists «*Tetradella*» sp. (here = *Tallinnella primaria*).

The present study is based on material preserved in the Paleontological Museum of the University in Oslo. Additional forms will no doubt be found when they are sought for in the Lower Ordovician of the Oslo Region. A careful collecting of samples from smaller rock-units than those usually employed is necessary to establish the detailed vertical distribution of the ostracods. As a systematic collecting of the Lower Ordovician ostracods in the Oslo Region would require considerable time, it is considered useful to present this paper now on the forms known up to the present, with the available (although not very detailed) data on their vertical distribution.

Lower Ordovician ostracods have so far only been reported from three districts in the Oslo Region. They will no doubt be found in other districts as well, when systematically sought for.

The writer wishes to express his sincere thanks to Prof., Dr. E. Stensiö (Paleozoological Department of the State Museum of Natural History, Stockholm) for placing at his disposal Swedish material of a form assigned here to *Rigidella erratica.* The writer's thanks are furthermore due to Miss B. Mauritz for photographing the ostracods.

Abbreviations:

P.M.O. = Paleontological Museum of the University in Oslo.

R.M. = State Museum of Natural History, Paleozool. Dept., Stockholm.

Notes on the Faunas.

Nanopsis nanella is of doubtful systematic position, but may be the earliest known form probably belonging to the paleocop ostracods, occuring as it does in the Ceratopyge Limestone (3aγ), usually assigned to the uppermost Tremadoc. It may be useful for correlation as it occurs in more or less contemporaneous beds in Sweden.

Tallinnella primaria and *Conchoprimitia eos* sp.n. from the Planilimbata Beds (3bγ-δ) may be the earliest known unquestionable paleocop ostracods.

The first richer ostracod faunas of the Oslo Region are those from the Megalaspis Limestone (3cα) and Asaphus Shale (3cβ). They are of special interest as contemporaneous faunas have been described in detail from Dalecarlia (Dalarna) in Sweden by Hessland (1949).

Several species are common to Dalecarlia and the Oslo Region, such as *Glossomorphites acuta*, *G. lingua*, *Aulacopsis bifissurata*, *Tallinnella grewingkii*, and *Steusloffia polynodulifera* (here = *S. acuta*). The Glossomorphitinae appear especially to be useful for correlation as they are easily recognized and appear to have rather restricted vertical ranges. The Norwegian faunas are as yet not well enough known, either as to number of forms or as to vertical range in detail, but a preliminary comparision shows that the faunas of 3cα and 3cβ correspond very well to those of the lower part of the Lower Grey Orthoceras Limestone and the very top of the underlying Lower Red Orthoceras Limestone in Dalecarlia, whereas the fauna of the upper part of the Lower Grey Orthoceras Limestone has not been found in Norway and may possibly be expected in the Endoceras Limestone (3cγ). It is noteworthy that the commonest *Conchoprimitia* form in 3cβ (*C. socialis vulgaris* subsp.n.) is replaced by a related and also very common form in Dalecarlia (*C. micropunctata*).

SYSTEMATIC DESCRIPTIONS

Suborder PALEOCOPA, Henningsmoen, 1953.
Superfamily Beyrichiacea Ulrich & Bassler, 1923
Family Sigmoopsiidae Henningsmoen, 1953
Subfamily Glossomorphitinae (Henningsmoen, 1953) Hessland, 1953

Genus *Glossomorphites* Hessland, 1953

Type species: — By original designation, *Glossopsis lingua* Hessland, 1949.

Glossomorphites lingua (Hessland, 1949).

Pl. 1, fig. 5.

Remarks: — *Glossomorphites* is proposed as a new name for *Glossopsis* Hessland, 1949, non Busch, 1904 by Hessland (1953).

1949 *Glossopsis lingua* n. sp. — Hessland, p. 298, pl. VIII, figs. 7—9, pl. XIII, fig. 4, pl. XV, fig. 18. (Detailed descriptions).

1949 *Glossopsis clavata* n. sp. — Hessland, p. 308, pl. VIII, figs. 1—5, pl. XIII, fig. 5, pl. XV, fig. 17. (Detailed description).

1951 *Glossopsis lingua* HESSLAND—KESLING, p. 160, pl. VII, figs. 2a-b. (To illustrate carapace terms.)
1953 *Glossopsis lingua* HESSLAND—HENNINGSMOEN, p. 202, text fig. 2:8. (Suggests that *G. clavata* represents the other sex.)

Type data: — Holotype (by original designation) is the left valve figured by HESSLAND, 1949 (pl. VII, figs. 7a-b) from the Lower Ordovician, Granmor, Dalarna (Dalecarlia), Sweden.

Material: — A few valves, preserved in limestone.

Remarks: — As discussed by HENNINGSMOEN (1953, p. 202), *G. lingua* and *G. clavata* are probably sexual dimorphs of the same species; *G. lingua* probably representing the male type. The Norwegian material corresponds very well with the Swedish, as described by HESSLAND. Both dimorphs occur assosiated.

Occurrence: — Asaphus Shale (3cβ): Oslo—Asker (Stensberggata in Oslo, Huk in Bygdøy, Slemmestad). — Sweden (Lower Red and Lower Grey Orthoceras Limestone, Dalecarlia).

Glossomorphites acuta (HESSLAND, 1949)

1949 *Glossopsis acuta* n. sp. — HESSLAND, p. 300, pl. VII, figs. 23—25, (Detailed description.)
1949 *Glossopsis tenuilimbata* n. sp. — HESSLAND, p. 303, pl. VII, figs. 21—22, pl. XIII, fig. 3, pl. XV, fig. 16. (Detailed description.)
1953 *Glossopsis acuta* HESSLAND—HENNINGSMOEN, p. 202. (Suggests that *G. tenuilimbata* represents the other sex.)

Type data: — Holotype (by original designation) is the left valve figured by HESSLAND, 1949 (pl. VII, fig. 24) from the Lower Grey Orthoceras Limestone, Stenberg, Dalecarlia, Sweden.

Material: — A few valves, preserved in limestone.

Remarks: — As discussed by HENNINGSMOEN (1953, p. 202), *G. tenuilimbata* is probably the male type of *G. acuta*. Both types occur associated in the Norwegian material, which agrees very well with the Swedish. It is possible that *G. acuta* (and other species of *Glossomorphites*) may prove to be synonyms of ostracod species described from glacial drift boulders in N. Germany. At present the German material is too insufficiently known to permit detailed comparisons.

Occurrence: — Megalaspis Limestone (3cα): Oslo—Asker (Hammersborg in Oslo, Vekkerøy), Asaphus Shale (3cβ): Oslo—Asker (Stensberggata in Oslo). — Sweden (Lower Grey and Lower Red Orthoceras Limestone, Dalecarlia), Denmark (Collected by the writer from Umbonata Limestone in Bornholm).

Genus *Aulacopsis* HESSLAND, 1949

Type species: — By original designation, *Aulacopsis bifissurata* HESSLAND, 1949.

Aulacopsis bifissurata HESSLAND, 1949

1949 *Aulacopsis bifissurata* n. sp. — HESSLAND, p. 287, pl. VII, figs. 13—20; pl. XIII, fig. 2. (Detailed description.)

1951 *Aulacopsis bifissurata* HESSLAND—KESLING, p. 160, pl. VII, fig. 4. (To illustrate carapace terms.)

Type data: — Holotype (by original designation) is the carapace figured by HESSLAND, 1949 (pl. VII, fig. 15) from the Lower Grey Orthoceras Limestone at Stenberg, Dalecarlia, Sweden.

Material: — A few valves, preserved in limestone.

Remarks: — The two characteristic fissures of this species (the presulcate and postsulcate fissure) are only faintly developed in the rather few Norwegian specimens known. At first glance they may thus remind one of *A. monofissurata* HESSLAND, 1949 or *A. plana* (HESSLAND, 1949) (transferred from *Ctenentoma* to *Aulacopsis* by HENNINGSMOEN, 1953, p. 202). Even in some of the Swedish specimens of *A. bifissurata,* however, the two fissures may be rather shallow and faint (cf. HESSLAND, 1949, pl. VII, figs. 17—18).

Occurrence: — Asaphus Shale (3cβ): Oslo—Asker (Stensberggata in Oslo, Slemmestad, Toje). — Sweden (Lower Red and Lower Grey Orthoceras Limestone, Dalecarlia).

Family Tetradellidae SWARTZ, 1936

Subfamily Tetradellinae SWARTZ, 1936

Genus *Tallinnella* ÖPIK, 1937

Type species: — By original designation, *Tallinnella dimorpha* ÖPIK, 1937.

Remarks: — The genus *Tallinnella* is employed here in the wide sense proposed by HENNINGSMOEN (1953, p. 214), who restricts *Tetradella* to the *Tetradella quadrilirata* group (developing submarginal loculi) and transfers the *subquadrans* group to *Tallinnella*.

Tallinnella primaria (ÖPIK, 1935)

Pl. 1, fig. 4.

1935 *Tetradella primaria* n. sp. – ÖPIK, p. 10, pl. 1, fig. 4. (Description of right valve.)
1949 *Tetradella primaria* ÖPIK—HESSLAND, p. 342. (Mentioned.)
1953 *Tallinnella primaria* (ÖPIK) — HENNINGSMOEN, pp. 194, 213. (Mentioned.)

Type data: — Holotype (by original designation) is the right valve figured by ÖPIK, 1935 (pl. I. fig. 4) from the Megalaspis Limestone (BIIγ) in a deep boring at Ubja, Esthonia.

Material: — A few valves, preserved in limestone.

Description of present material: — Length (including frill) 1.2 mm, height (including frill) 0.8 mm. Outline truncate elliptical. Posterior cardinal angle obtuse, anterior cardinal angle concealed by the frill. The angle between the frill and the dorsal margin is markedly more obtuse than the posterior cardinal angle. Greatest height at midline.

The relief is pronounced. The lobes are as a whole of medium width, about as wide as the intervening sulci. L1 and L4 are connected through a ventral ridge to form an even, curved ridge (carinal ridge) parallel to the free margins. L1 turns slightly backwards in its upper end, whereas L4 does not reach the dorsal margin. L2 short and slightly bulbous dorsally. L3 long and slightly oblique; its dorsal end points upwards and slightly backwards, but is almost straight. L2, L3 and the part of the connecting ridge uniting these are slightly higher than the rest of the lobes. S1 and S2 are well defined, but S1 is rather short and narrow. S3 is less well defined. There is a marked groove-like depression between the carinal ridge and the velate frill. The frill is rather wide, and is widest anteroventrally. It is slightly convex. It becomes rather narrow posteriorly and continues as a lobe-like ridge where it is parallel to the posterior margin. It extends as far up dorsally as L4 does.

The surface appears to be smooth. There is a faint indication of a lineate structure in the frill in its longitudinal direction.

Remarks: — The one specimen known from 3b appears to have a more bulbous L2 than those in 3c*α*, the latter agreeing better with the holotype and some material collected by the author from the Umbonata Limestone in Bornholm, Denmark. The material is, however, too scanty to judge whether these two forms belong to different groups of the species or may be ascribed to individual variation. The specimen from 3b may be the oldest known unquestionable tetradellid known up to the present.

Occurrence: — Planilimbata Beds (3b*γ*—*δ*): Ringsaker (Heramb), — Megalaspis Limestone (3c*α*): Oslo—Asker (Slemmestad, Vekkerøy). — Esthonia (Megalaspis Limestone, Ubja), Denmark (Umbonata Limestone, Bornholm).

Tallinnella grewingkii (Bock, 1867)

1867 *Beyrichia Grewingkii* — Bock, p. 592. (Short description.)
1869 *Beyrichia Grewingkii* Bock—Bock, p. 186. (Listed.)
1882 *Beyrichia nana* n. sp. — Brögger, p. 55, pl. XII, fig. 15. (Description of internal mould. Claimed to be *T. grewingkii* by Hessland, 1949, p. 342.)
1886 *Beyrichia Grewingkii* Bock—Jones & Holl, p. 362. (Mentioned.)
1889 *Beyrichia erratica* n. sp. (pars) — Krause, p. 18, pl. II, fig. 6. (Identity suggested by Öpik, 1935, pp. 10—11 and by Hessland, 1949, p. 344.)
1891 *Beyrichia erratica* var. *granulata* — Krause, p. 500. (Name introduced for the above-mentioned form.)
1934 *Beyrichia* (*?Bollia*) *grewingki* Bock—Bassler & Kellett, p. 193.
1935 *Tetradella grewingki* (Bock) — Öpik, p. 9, pl. II, figs. 1a-b. (Description and figures of lectotype.)
1939 *Tetradella grewingki* (Bock) — Öpik, p. 139, pl. II, fig. 13. (Figures external impression of right valve from 3c*β* at Krekling, Norway.)
1941 *Tetradella* (*Tallinnella*) *grewingki* (Bock) — Schmidt, p. 38. (Mentioned.)
1949 *Tetradella grewingki* (Bock) — Hessland, p. 342, pl. XI, figs. 3, 5—9, 11; pl. XV, fig. 13. (Detailed description and discussion of species.)
1949 *Tallinnella grewingki* (Bock) — Henningsmoen in Dons & Henningsmoen, p. 28. (Mentioned.)
1953 *Tallinnella grewingki* (Bock) — Henningsmoen, p. 214. (Mentioned.)

Type data: — Lectotype is a left valve from the *expansus* zone at Obuchowo, Wolchow, Ingermanland, U.S.S.R. Designated by Öpik, 1935 (pl. II, figs. 1a—b).

Material: — Several valves and internal moulds preserved in limestone.

Remarks: — The Norwegian material corresponds closely with the Swedish material as described by HESSLAND (1949). The usual form is that figured by him in pl. IX, fig. 3, and this also seems to agree best with the lectotype. It may be added that the anterior part of the velate frill may be more or less convex in specimens of the same size in the same slab. It is difficult to see whether this is due to dimorphism, or whether there are intermediate stages.

Beyrichia nana (BRÖGGER, 1882) appears to be the internal mould of *Tallinnella grewingkii*, as pointed out by HESSLAND (1949, p. 342). It is stated to occur in Ceratopyge Limestone (3aγ), but the associated fauna (i.a. *Conchoprimitia* sp.) shows that it is not from 3aγ, and it was probably collected in a limestone nodule of the Asaphus Shale (3cβ). It may be added that the collector, TH. MÜNSTER, has collected fossils from 3cβ and 3cγ at the same locality; Tøyen in Oslo.

Occurrence: — Asaphus Shale (3cβ): Oslo—Asker (Tøyen, Stensberggata, Slemmestad), Eiker—Sandsvær (Muggerud, Sandbakk). — U.S.S.R. (*expansus* shale, Ingermanland), Sweden (Lower Grey and Lower Red Orthoceras Limestone, Dalecarlia), Germany (glacial drift boulders).

Subfamily Bassleratiinae SCHMIDT, 1941

Genus *Rigidella* ÖPIK, 1937

Type species: — By original designation, *Steusloffia mitis* ÖPIK, 1935 (possibly a synonym of *Beyrichia erratica* KRAUSE, 1889).

Rigidella erratica (KRAUSE, 1889)

Pl. 1, figs. 2—3.

1889 *Beyrichia erratica* n. sp. — KRAUSE, p. 18, pl. II, figs. 7—8 (not fig. 6 = *Tallinnella grewingkii*). (Description.)
1893 *Tetradella erratica* KRAUSE—ANDERSSON, p. 128. (Listed.)
1934 *Tetradella? erratica* (KRAUSE) — BASSLER & KELLETT, p. 480.
?1935 *Steusloffia mitis* n. sp. — ÖPIK, p. 11, text fig. 4, pl. I, fig. 5. (Description.)
?1937 *Steusloffia mitis* A. Ö., genotype of *Rigidella* n. gen. — ÖPIK, p. 53. (Mentioned.)
1937 *Rigidella erratica* (KRAUSE) — ÖPIK, p. 53. (Mentioned.)

1941 *Tetradella erratica* (KRAUSE) — SCHMIDT, p. 40. (Discussed.)
1941 *Rigidella krauseana* n. nom. — SCHMIDT, p. 40. (Suggests this name for the specimen figured by KRAUSE, 1889, pl. II, fig. 8 as *Beyrichia erratica*.)
?1941 *Rigidella mitis* (ÖPIK) — SCHMIDT, p. 40. (Listed.)
?1949 *Tetradella* (*Rigidella*) *mitis* (ÖPIK) — HESSLAND, p. 340. (Discusses the position of *Rigidella*.)
?1953 *Rigidella mitis* (ÖPIK) — HENNINGSMOEN, p. 221, text figs. 10a-c. (Discussion of species.)
1953 *Rigidella* cf. *mitis* (ÖPIK) — HENNINGSMOEN, p. 222, text fig. 9d, pl. 1, figs. 3—4. (Remarks.)

Type data: — Lectotype (subsequent designation by ÖPIK, 1935, p. 11) is the left valve figured by KRAUSE, 1889 (pl. II, fig, 7) from a glacial drift boulder in N. Germany.

Remarks: — When erecting this species, KRAUSE (1889) depicted three somewhat different specimens (l.c., pl. II, figs. 6—8), the one (fig. 8) described as a variety and later by him (1891) given the name *Beyrichia erratica* var. *granulosa*. This form is now believed to be a synonym of *Tallinnella grewingkii* (cf. above). The specimen shown in fig. 7 was designated the type of *erratica* by ÖPIK, 1935 (p. 11). The third of KRAUSE's specimens (fig. 6) differs in being more swollen at the ventral end of L3, and was given the name *Rigidella krauseana* by SCHMIDT, (1941, p. 40). The ventral end of L3 appears to be sometimes more and sometimes less swollen in the Scandinavian material assigned below to *Rigidella erratica*, and for that reason *R. krauseana* is regarded here as a synonym of *R. erratica*. HENNINGSMOEN (1953, p. 221, text figs. 10a-c) gives a new reconstruction of *R. mitis*, which was erected on a partly exfoliated specimen. If this reconstruction is correct, *R. mitis* is probably a synonym of *R. erratica*. In the same paper (p. 222) a Swedish form is referred to as *R.* cf. *mitis* and suggested possibly to be conspecific with *R. erratica*. This form is believed here to be referable to *R. erratica*, which is also made likely by the fact that the Swedish form and the lectotype seem to be associated with the same ostracod species, and thus probably come from the same horizon. The lectotype is associated with *Tallinnella grewingkii* and *Laccochilina schmidtii* (KRAUSE, 1889), whereas the Swedish form is associated with *Tallinnella grewingkii* and a *Laccochilina* species which is not well preserved, but may well be *L. schmidtii*.

Present material: — Besides Norwegian material (separate valves preserved in limestone) the writer has also had the privilege to study better preserved Swedish material, thanks to the courtesy of Prof., Dr. E. Stensiö, Stockholm.

Description of Swedish material: — The following description is based on a well preserved left valve from a glacial drift boulder, collected by Prof., Dr. E. Stensiö in Humlenäs, Kristdala, Småland, Sweden, and belonging to the Paleozoological Department of the State Museum of Natural History, Stockholm (RM. — Ar 18690). It was figured by HENNINGSMOEN, 1953 (pl. 1, figs. 3—4). New photographs are given in the present paper (pl. 1 figs 2—3).

Length 0.95 mm, height 0.6 mm. Outline truncate elliptical. Both cardinal angles slightly obtuse. Ends subequal (disregarding frill). Greatest height in anterior half.

Trilobate, L3 and L4 being fused. The part corresponding to the lower half of L3 is, however, developed as a node-like elevation. Behind this node there is a semisulcus (sulcoid bend), corresponding to the lower half of S3. L1 faintly developed, rather fused with the extralobal area. L2 rather well defined, bulbous in its upper part. S1 rather shallow and not well defined, S2 well defined, slightly geniculate. The lobes are superimposed by crests, C1—C4. Only C2 fails to reach the dorsal crest. C3 also traverses the node corresponding to the lower part of L3. C4 is located in what corresponds to the anterior part of L4. The crests are joined ventrally by a connecting crest, uniting C1 and C4 into a continuous curved crest (carinal crest).

Velate frill narrow, almost normal to the valve surface proper. It runs parallel to the anterior and ventral margin, and is developed as a crest posteriorly, here resembling the crests of the lobal area. The distance between this velate crest and C4 is markedly greater than the distance between C3 and C4. Dorsally the velate structure is confluent with the dorsal crest, which is developed parallel to the dorsal margin.

Surface finely granulate, especially anteriorly.

Variation: — Other specimens may vary in minor details. L3 may be developed as an elongate node (not only in its ventral part). Even then, there is only a semisulcus between L3 and L4. The distance between the velate crest posteriorly and C4 may be shorter. The carinal crest (C1 + connecting crest + C4) may be more evenly curved than in the figured specimen. These variations correspond more or less to those in *Tallinnella grewingkii* (cf. HESSLAND, 1949, pl. IX, figs. 3, 5—9, 11), and should probably be regarded as intraspecific. For this reason *R. krauseana* is regarded as a synonym of *R. erratica.*

Norwegian material: — This shows the same variation as the Swedish. Sometimes there is even a faint sulcus between L3 and L4, thus approaching *Tallinnella grewingkii.* The frill may be sligtly wider, too, and faintly radially striate.

Affinities: — *Rigidella erratica* is no doubt close to *Tallinnella lanceolata* (HESSLAND, 1949) and *T. grewingkii,* but appears also to be close to early *Steusloffia* species. If *Steusloffia* belongs to the Bassleratiinae (as suggested by HENNINGSMOEN, 1935, p, 220), *Rigidella* is intermediate between the Tetradellinae (with *Tallinnella*) and the Bassleratiinae. However, the boundary between these two subfamilies has to be drawn somewhere, and it was suggested by HENNINGSMOEN (1953, p. 221) that the forms where a true S3 is not developed should be assigned to the Bassleratiinae. This places *Rigidella* in the Bassleratiinae.

Occurrence: — Megalaspis Limestone (3cα): Oslo—Asker (Slemmestad). —Sweden (glacial drift boulders of Megalaspis Limestone in Småland), N. Germany (glacial drift boulders), ?Esthonia (*R. mitis* in Megalaspis Limestone).

Genus *Steusloffia* ULRICH & BASSLER, 1908.

Type species: — *Strepula linnarssoni,* KRAUSE, 1889, by subsequent designation of ULRICH & BASSLER, 1923 (p. 308). According to THORSLUND, 1940 (p. 176), *Strepula linnarssoni* is a synonym of *Beyrichia costata* LINNARSSON, 1869.

Steusloffia acuta (KRAUSE, 1891)

1891 *Beyrichis erratica* var. *acuta* n. v. — KRAUSE, p. 499, pl. XXXI, fig. 18. (Description.)

1894 *Strepula lineata* var. *separata* n. v. — STEUSLOFF, p. 785, pl. LVIII, figs. 23a-b. (Description.)

1908 *Beyrichia* (*Steusloffia*) *acuta* (KRAUSE) — ULRICH & BASSLER, pp. 285, 296, text fig. 51, pl. 38, fig. 4. (Mentioned.)
1924 *Steusloffia* (*Strepula*) *lineata* var. *separata* STEUSL. — KUMMEROW, p.407. (Discussed.)
1934 *Steusloffia acuta* (KRAUSE) — BASSLER & KELLETT, p. 475.
1935 *Steusloffia acuta* (KRAUSE) — ÖPIK, p. 11. (Mentioned.)
1937 *Rigidella acuta* (KRAUSE) — ÖPIK, p. 53. (Listed.)
1937 *Rigidella separata* (KRAUSE) — ÖPIK, p. 53. (Listed.)
1941 *Rigidella acuta* (KRAUSE) — SCHMIDT, p. 40. (Listed.)
1941 *Rigidella separata* (KRAUSE) — SCHMIDT, p. 40. (Listed.)
1949 *Steusloffia lineata* var. *separata* (STEUSLOFF) — HESSLAND, p. 353. (Mentioned.)
1949 *Steusloffia polynodulifera* n. sp. — HESSLAND, p. 355, pl. X, figs. 1—7; pl. XIV, fig. 3. (Detailed description.)
1953 *Steusloffia polynodulifera* HESSLAND — HENNINGSMOEN, pp. 217, 220, 223, 234, (Mentioned.)

Type data: — Holotype (by monotypy) is the right valve figured by KRAUSE, 1891 (pl. XXXI, fig. 18), from a drift boulder of glauconitic limestone in N. Germany.

Material: — A few valves preserved in limestone.

Remarks: — In 1889 KRAUSE described *Strepula* (now *Steusloffia*) *lineata* from a glacial drift boulder in N. Germany. C3 and C4 meet both dorsally and ventrally, although they are erroneously depicted as not meeting ventrally. Later, STEUSLOFF (1894, pp. 781, 785) described two varities as var. *granulosa* and var. *separata*. As suggested by KUMMEROW (1924, p. 408), *granulosa* may be a synonym of *lineata*, the differences stated probably being due to the preservation. KUMMEROW maintains further that var. *separata* is also a synonym of *lineata*. The form *separata* differs, however, from *lineata* (and *granulosa*) in not having C3 and C4 united dorsally. This is, moreover, a constant feature in *Steusloffia polynodulifera* HESSLAND, 1949, which probably is a synonym of *separata*. It thus appears that *separata* represents a separate form. On the other hand, *separata* (and thus probably *polynodulifera*) is most probably a junior synonym of *S. acuta*. The differences between the type specimens of *acuta* and *separata* are no greater than within the specimens assigned to *S. polynodulifera* (cf. HESSLAND, pl. X, figs. 1—7).

The Norwegian material agrees quite well with the Swedish material of *S. polynodulifera*.

Occurrence: — Asaphus Shale (3cβ): Oslo-Asker (Tøyen, Slemmestad), Eiker—Sandsvær (Muggerud). — Sweden (Lower Grey and Upper Red Orthoceras Limestone, Dalecarlia), N. Germany (glacial drift boulders).

Incertae familiae.

Genus *Nanopsis* gen.n.

Name: — From Gr. *νάννος* (dwarf) and Gr. *ὄψις* (appearance).

Type species: — *Beyrichia nanella* Moberg & Segerberg, 1906.

Diagnosis: — Small, straight-hinged valves with short sulcus. Small nodes may be developed in anterior half of valve. No submarginal structures (velate or carinal structures).

Affinities: — The systematic position of this genus is uncertain. The genus reminds one of some Cambrian bivalves now assigned to the Archaeostraca, as f. inst. *Bradoria* Matthew, 1899. The sulcus indicates, however, that *Nanopsis* belongs to the ostracods (Beyrichiacea?). If so, it is one of the earliest known ostracods.

Nanopsis nanella (Moberg & Segerberg, 1906)

Pl. 1, fig. 1.

1906 *Beyrichia nanella* n. sp. — Moberg & Segerberg, p. 76, pl. III, figs. 27—28. (Description.)

1934 *Beyrichia? nanella* Moberg & Segerberg — Bassler & Kellett, p. 201.

Type data: — As lectotype is chosen here the left valve figured by Moberg & Segerberg, 1906 (pl. III, fig. 28) from Ceratopyge Shale at Ventlinge, Öland, Sweden.

Material: — Several valves, preserved in limestone.

Diagnosis: — A *Nanopsis* species with two small nodes in front of the sulcus and near the dorsal margin. The anterior node is the larger, and situated slightly further up dorsally. Size of adult valves c. 0.7 × 0.4 mm.

Description: — The valves attain a size of c. 0.7 × 0.4 mm. Hinge line straight, free margins with slight forward swing. Cardinal angles obtuse; anterior cardinal angle slightly less obtuse than posterior. Valves rather convex. Sulcus short and comparatively wide. Two small nodes are developed in front of the sulcus and near to the dorsal border. The anterior node is the larger and is also situated slightly further up dorsally. A narrow and short sulcus-like depression is developed between the two nodes. There are no submarginal structures. Surface seems smooth.

Affinities: — *Nanopsis nanella* recalls such forms as *Primitiella brevisulcata* HESSLAND, 1949. This Lower Ordovician species has also a short sulcus and may develop small nodes, and is possibly congeneric with *Nanopsis nanella*, but differs i.a. in not having so well-developed nodes.

Occurrence: — Ceratopyge Limestone (3aγ): Oslo—Asker (Slemmestad). —Sweden (Ceratopyge Shale, Öland; Shumardia zone, Scania).

Superfamily Leperditiacea BASSLER & KELLETT, 1934

?Family Leperditellidae ULRICH & BASSLER, 1906

?Subfamily Conchoprimitiinae HENNINGSMOEN, 1953

Genus *Conchoprimitia* ÖPIK, 1935

Type species: — By original designation, *Conchoprimitia gammae* ÖPIK, 1935 (possibly a synonym for *Primitiella glauconitica* KUMMEROW, 1924; cf. HENNINGSMOEN, 1953, p. 253).

Remarks: — *Conchoides* HESSLAND, 1949 is regarded as a synonym for *Conchoprimitia* by HENNINGSMOEN, 1953, p. 253.

Blood canals in Conchoprimitia: — In 1909 BONNEMA (p. 18) described two short subvertical ridges in an internal mould of *Conchoprimitia tolli* (BONNEMA), one in front of and one behind the adductor muscle scar. They would correspond to grooves in the internal surface of the valve, and they were suggested to stand in relation to «Blutgefässe». Both the grooves and the ridges were illustrated by ÖPIK (1937, p. 10, pl. XV, figs 1—2), who referred to them as «vascular impressions». ÖPIK later (1939, p. 139, pl. I, fig. 7) reported such «Gefässabdrücke» also in *C. socialis* (here = *C. socialis vulgaris* subsp. n.). His figure shows that both ridges in the internal mould branch into finer ridges ventrally. In an interesting mould (P.MO. — 2351; pl. 2. figs. 3—5) of the present material of *C. socialis vulgaris* the branching and radiating ridges can be traced for a longer distance, at least beyond the submarginal bend, but they are apparently wanting in the concave border zone of the mould. The finer ridges fork and anastomize, forming a network which also unites the finer ridges of the two ridge systems. The two main grooves have also been observed in the internal surface of a valve of *C. eos* sp. n. (cf. below).

Rather similar markings have long been known in the Leperditiidae, and were referred to as «Gefässe» by FR. SCHMIDT (1873). They were called «venose markings» and «venose lines» by SWARTZ (1949), whereas KESLING (1951, p. 121) gives the term «blood canals», defined as «certain branched grooves on the interior of valves, which are assumed to mark the position of former blood vessels». TRIEBEL (1941, p. 331) states that there can hardly be any doubt that they represent «Blutkanäle», and he points out that such blood canals have been described in some recent ostracods (Cypridinidae) by CLAUS (1876, p. 93). TRIEBEL furthermore gives a figure (1941, pl. 6, fig. 63) of the interior of a valve of *Cypridina vanhöffeni* G. W. MÜLLER, which clearly shows the pattern of the blood canals. They radiate from the adductor muscle scar area, i.e. an area where the main body of the animal is connected with the carapace. The same is true in *Conchoprimitia* and in the leperditiids, and it thus seems reasonable to believe that they are connected with the blood system in these Paleozoic ostracods.

The system of blood canals in *Conchoprimitia* apparently differs from that in leperditiids in radiating from two main canals, one in front of, and one behind the adductor muscle scar, whereas a great number of canals radiate from the muscle scar in the leperditiids.

Blood canals are known from several Paleozoic ostracod genera, as *Dihogmochilina*, *Eoleperditia*, *Herrmannina*, *Hogmochilina*, *Isochilina*, *Leperditia*, and *Saffordellina* (all of the Leperditiidae), *Conchoprimitia* (possibly also a Leperditiacean) and the genus *Bernix*, a Beyrichiacean (Kloedenellidae?), and also in the Beyrichiidae, as in *Mastigobolbina incipiens* ULRICH & BASSLER, 1923, and probably also in *Beyrichia? clathrata* JONES, 1858.

TRIEBEL (1941), p. 331) points out that the presence of blood canals shows that these ostracods had a heart. In recent ostracods a heart is only known in the Myodocopa, but it has long been assumed that the «protostracods» had a heart (cf. SKOGSBERG, 1920, p. 75). It is important that at least some genera of the Paleocopa (Beyrichiacea + Leperditiacea) appear to have had a heart, as this would further distinguish this suborder from the «recent» suborders, with the exception of Myodocopa, which, however, differs in having a rostral incisure.

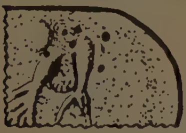

Fig. 1. Anterodorsal quadrant of internal mould (P.M.O. — 2351) of *Conchoprimitia socialis vulgaris*, showing blood canals, adductor muscle scar (between the two main canals), and pits (accessory muscle marks?). Approximately ×10. Compare with pl. 2, figs. 3—5.

Muscle marks in Conchoprimitia: — The subelliptical adductor muscle scar is sometimes faintly visible on the external surface of the valve (Pl. 1 fig. 9). When a sulcoid depression is present, the scar is developed in the ventral end of it. No individual spots (bosses) have been observed in the scar, as in the scars of the Leperditiidae (cf. SWARTZ, 1949 and SCOTT, 1951). However, in the same internal mould (P.M.O. — 2351) which shows the blood canals so well, the surface of the impression of the muscle scar is somewhat uneven, and appears slightly radially plicate along its ventral border (Pl. 2 fig. 5). In the same mould there are some deep pits partly inside and partly around the sulcoid depression. These pits (or rather the corresponding tubercles in the interior of the valve) probably represent accessory muscle scars. Similar structures are known also in recent ostracods, as in *Ilyocypris bradyi* G. O. SARS and *I. gibba* (RAMDOHR) (see TRIEBEL, pl. 1, figs. 1—2, 4—5). They represent points of attachment of muscles and are divided into three groups by TRIEBEL (1941, p. 297); «dorsale», «antennale», and «mandibulare Gruppe». The two former correspond to the «peripherische Gruppe», and the latter + the adductor muscle scar to the «zentrale Gruppe» of ZALANYI (1929, p. 11). Returning to the present mould (see also text figure 1), there is one pit at the edge of the sulcoid depression, just above the posterior main blood canal, and three pits inside the depression, dorsal to the adductor muscle scar. At least the three latter pits probably represent the dorsal group, which belongs to muscles that join the valve with the dorsum of the animal. Two other pits are developed in front of the sulcoid depession (and in front of the anterior main blood canal), one in front of the dorsal group, and one in front of the aductor scar. These two pits may represent the antennal group, the upper probably belonging to an antennule muscle and the lower to an antenna muscle. There are no pits anteroventrally to the adductor scar, corresponding to attachment points of the mandible muscles, unless the depressions between some of the first branches in the anterior blood canal system represent such pits. The relative position of the adductor scar, the dorsal group of pits and the antennal group is rather similar to that in f. inst. *Ilyocypris*, and supports the present orientation of *Conchoprimitia*. It may be added that a number of accessory muscle scars have been described in the Leperditiidae by SWARTZ (1949) and SCOTT (1951).

Conchoprimitia eos sp. n.

Pl. 1, figs. 6—7.

Name: — The name *eos* refers to the early occurence of this species, which is the earliest known *Conchoprimitia*.

Type data: — Holotype (P.M.O.—66382a) is a left valve from the Planilimbata Beds (3bγ—δ) at Heramb, Ringsaker, collected by S. Skjeseth, 1950.

Material: — About 10 valves, including one showing the internal surface of the valve. Preserved in limestone.

Diagnosis: — A medium-sized *Conchoprimitia* species with leperditioid outline, and height-length proportion in adult valves c. 0.63—0.65. Surface appears smooth, but is slightly rough, although there are no distinct pits or granules.

Description: — Largest specimen 2.33 mm long. Outline leperditioid, posterior end being less tapering than anterior end. Greatest height slightly behind midline. Height-length proportions measured vary from 0.63 to 0.65. Hinge line straight, cardinal angles obtuse (anterior angle c. 130°, posterior angle c. 125°), free borders evenly curved, but the anterior free border is more convex than the ventral and posterior free borders. Anterior end markedly more gibbous than posterior end. The ventral anterior border areas are steeper than the dorsal and posterior border areas.

A very faintly depressed area dorso-centrally and in front of the midline represents the adductor muscle scar. On the *internal* surface of the valve (Pl. 1, fig. 6) it is represented by a low, round elevation. Dorsal to this elevation there is a low, vertical ridge (which would give a sulcus-like impression in an internal mould). Just in front of and just behind the muscle spot is a straight groove. These two grooves diverge ventrally, and represent the two main blood canals also known in other species of *Conchoprimitia* (cf. p. 55).

Surface appears smooth, but is slightly rough on a very small scale; however, no distinct pits or granules are developed.

Affinities: — This species is probably related to C. *socialis* and allied, but differs in not having a pitted surface. Furthermore *C. eos* appears to be smaller than *C. socialis*.

Occurrence: — Planilimbata Beds (3bγ—δ) at Ringsaker (Heramb).

Conchoprimitia socialis socialis (Brögger, 1882)

Pl, 2, figs. 7—8.

1882 *Leperditia* (*Isochilina*?) *socialis* n.sp. (pars) — Brögger, p. 55, pl. XII, fig. 14. (Description.)
1934 *Isochilina*? *socialis* (pars) — Bassler & Kellett, p. 342.
1939 *Conchoprimitia broeggeri* n. sp. — Öpik, p. 140, pl. I, fig. 13. (Description.)
1949 *Conchoides socialis* (Brögger) (pars) — Hessland, p. 155, pl. I, figs. 3—4. (Description.)
?1949 *Conchoides microputntata* n. sp. — Hessland, p. 151, pl. I, figs. 1—2, pl. XII, fig. 1, pl. XV, fig. 1. (Description.)
1949 *Conchoides broeggeri* Öpik — Hessland, p. 151. (Mentioned.)
1953 *Conchoprimitia socialis* (Brögger, 1882) (pars) — Henningsmoen, p. 253. (Mentioned.)
1953 *Conchoprimitia broeggeri* Öpik — Henningsmoen, p. 253. (Mentioned.)
?1953 *Conchoprimitia micropunctata* Hessland — Henningsmoen, p. 253. (Mentioned.)
non 1939 *Conchoprimitia socialis* (Brögger) — Öpik, p. 139, pl. I, fig. 13 (cf. below).

Type data: — Lectotype is the specimen (P.M.O.—20212; pl. 2, fig. 8) figured by Brögger (1882, pl. XII, fig. 14) from the lowermost part of 3cγ at Vestfossen, Eiker (not from 3cβ as stated by Brögger in the explanation of the figure). (Subsequent designation by Hessland, 1949, p. 154).

Material: — Several separate valves, preserved in limestone.

Diagnosis: — A large *Conchoprimitia* species (so far known, up to 4.55 mm long) with the height/length ratio in adult valves varying between 0.63 and 0.65. Ends subequal; outline only very slightly leperditoid (also in adult valves). Ventral border rather evenly curved. Surface very finely pitted.

Description: — Rather large, up to 4.55 mm long and 2.90 mm heigh. Height/length ratio in adult valves varies from 0.63 to 0.65. Ends subequal; outline only very slightly leperditioid. Cardinal angles obtuse (anterior angle c. 140°, posterior angle c. 130°). Free margins evenly curved. Greatest height at midline. Greatest width in the central area, where there is a faint, shield-like swelling. A sulcoid depression is only extremely faintly indicated. Adductor muscle scar may be discernible. Surface very finely pitted, except for the muscle scar and the shield-like swelling. Some scattered larger pits are also present. A short groove, parallel to the posterior margin, may be developed at the posterior corner.

Remarks: — When erecting this species, BRÖGGER (1882, p. 55) stated that it occurred both in the Expansus Shale (i.e. Asaphus Shale 3cβ) and in the lower part of the Orthoceras Limestone (i.e. Endoceras Limestone, 3cγ). ÖPIK (1939, p. 139) pointed out that the specimens in 3cγ differ from those in 3cβ. As BRÖGGER's type specimen was stated to come from 3cβ, ÖPIK restricted the name *socialis* to this form, and gave a new name, *broeggeri*, to the form from 3cγ. A re-examination of BRÖGGER's type specimen has, however, most unfortunately shown that it comes from the lowermost part of 3cγ. This is seen on the original label, and furthermore this specimen belongs to the form in 3cγ. There seems to be little chance of the specimen having been mixed up with another specimen as it agrees rather well with BRÖGGER's figure, and as there are no specimens of *Conchoprimitia* collected by BRÖGGER from 3cβ at Vestfossen. The result is that *C. socialis* has to be restricted to the form from 3cγ, which makes *C. broeggeri* ÖPIK, 1939 a synonym and leaves the form from 3cβ without a name. The latter form is described below as *C. socialis vulgaris* subsp. n.

Affinities: — When discussing the affinities of *C. micropunctata*, HESSLAND (1949, p. 151) states that *C. socialis* is proportionally shorter and higher. This is, however, due to the inclusion of ÖPIK's specimen of *C. socialis* (now *C. socialis vulgaris* subsp.n.) in the measured specimens. *C. socialis socialis* as defined here agrees very well with *C. micropunctata*. In HESSLAND's table of dimensions of *C.*

socialis (1949, p. 155) the figures for the length of the carapace (L) and for the length of the dorsal margin (DM) have been confused for the type specimen (this has also given wrong figures for H/L, DM/L, and FM/DM — naturally DM/L can not be greater than 1.0). As furthermore *C. socialis* shows the same type of surface ornamentation as *C. micropunctata*, the latter may probably be regarded as a junior synonym of *C. socialis socialis*. The only difference observed by the writer is that the Norwegian form may reach a larger size than the specimens of *C. micropunctata* described by HESSLAND.

Occurrence: — 3cγ (lower part) in Eiker—Sandsvær (Vestfossen), and in Oslo—Asker (Slemmestad). — Sweden (Lower Grey Orthoceras Limestone, Dalecarlia).

Conchoprimitia socialis vulgaris subsp.n.

Pl. 1, figs. 8—9, pl. 2, figs. 1—6, text-fig. 1.

1882 *Leperditia* (*Isochilina*?) *socialis* n. sp. (pars) — BRÖGGER, p. 55 (not pl. XII, fig. 14).

1939 *Conchoprimitia socialis* (BRÖGGER) — ÖPIK, p. 139, pl. I, fig. 7. (Remarks.)

1949 *Conchoides socialis* (BRÖGGER) (pars) — HESSLAND, p. 155 (not pl. I, figs. 3—4).

Name: — The name *vulgaris* is given as this form is very common in 3cβ, and apparently more common than the main subspecies is in 3cγ.

Type data: — Holotype is a left valve (P.M.O.—66422, pl. 2, fig. 6) from 3cβ (1.5 m above 3cα) at the small tongue of land N of Toje, near Slemmestad in Røyken.

Material: — Numerous valves and internal moulds of valves, preserved in limestone or shale.

Diagnosis: — A large (so far known up to 4.45 mm long) and comparatively high form of *Conchoprimitia* (height/length ratio usually between 0.69—0.73, but may go down to 0.66). Outline slightly leperditioid, at least in adult valves. Marginal surface rather steep, except postero-dorsally; the steepest area being postero-ventrally. Surface minutely punctate, with some scattered larger pits.

Description: — Rather large and high. Largest specimen measured is 4.45 mm long and 2.70 mm high, which gives a height/length ratio of c. 0.66. In most species measured, however, the height/length ratio varies between 0.69 and 0.73. Outline slightly leperditioid; greatest height in posterior half, slightly behind the midline. Cardinal angles obtuse (anterior angle c. 140°, posterior angle c. 130°). Free borders rather evenly convex. Lateral surface slightly convex, marginal surface strongly convex («steep») except posterodorsally. The steepest part of the marginal surface is situated slightly behind the midline, where the valve is highest. A usually faint sulcoid depression may be developed in front of the midline in the dosal half. Two low vertical ridges may sometimes be discerned, one just in front of an one just behind the sulcoid depression. They correspond in position to the two main blood canals in the internal surface of the valve (cf. above). The shell substance is somewhat thicker in a border zone along the free margins than in the rest of the valve, as shown by HESSLAND (1949, pl. XV, figs. 1—2) i.a. in *C. micropunctata* and *C. circumreticulata*. For this reason internal moulds of *C. socialis vulgaris* are concave in the border zone along the free margins, not convex as in the exterior surface of the valve. Sometimes a more or less faint groove is developed on the external surface parallel to the free borders, especially anterodorsally and posterodorsally. It appears that these grooves are developed just inside the thicker border zone. No attached instars have been observed in this form, as in some other species of *Conchoprimitia* (cf. HENNINGSMOEN, 1953 p. 251).

The external surface is densely covered by fine pits, with some larger pits scattered in between. The pits are not developed in the subelliptical muscle scar just below the sulcoid depression or in the faint shield-like swelling posteroventral to the scar. The pits may also be missing in parts of the marginal surface.

Affinities: — *C. socialis vulgaris* subsp.n, agrees with *C. socialis socialis* in attaining a large size, and in having a minutely punctate surface. It differs mainly in being proportionally higher. It is possible that there is an even transition from *C. socialis vulgaris* in 3cβ to *C. socialis socialis* in 3cγ, and *vulgaris* is proposed here as a subspecific name only, especially as BRÖGGER had no doubt the lower form in mind when he gave the name *socialis*, since *socialis vulgaris* usually occurs in associations of numerous individuals, whereas few and scattered specimens have been collected of *socialis socialis*.

Stratigraphical and Geographical Distribution of Lower Ordovician Ostracods of the Oslo Region	Horizons								Districts[1]		
	Ceratopyge Series (Tremadoc)			Asaphus Series (Arenig)							
	2e	3aα—β	3aγ	3bα—β	3bγ—δ	3cα	3cβ	3cγ	Eiker—Sandsvær	Oslo—Asker	Ringsaker
1. *Glossomorphites lingua* (HESSLAND)						1				1	
2. *Glossomorphites acuta* (HESSLAND)							2			2	
3. *Aulacopsis bifissurata* HESSLAND							3			3	
4. *Tallinnella primaria* (ÖPIK)					4	4				4	4
5. *Tallinnella grewingkii* (BOCK)						5	5		5	5	
6. *Rigidella erratica* (KRAUSE)						6				6	
7. *Steusloffia acuta* (KRAUSE)						7	7		7	7	
8. *Nanopsis nanella* (MOBERG & SEGERBERG)			8							8	
9. *Conchoprimitia eos* sp. n.					9						9
10. *Conchoprimitia socialis socialis* (BRÖGGER)								10	10	10	
11. *Conchoprimitia socialis vulgaris* subsp. n.							11		11	11	
12. *Conchoprimitia* spp.						12	12			12	

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[1] A map showing the Cambro—Silurian districts of the Oslo Region has recently been published by STØRMER (1953, p. 53).

Occurrence: — Asaphus Shale (3cβ): Oslo—Asker (Slemmestad, Bjerkåsholmen, Toje, Vekkerøy, Huk, Stensberggata), Eiker—Sandsvær (Sandbakk, Oppijordet).

Conchoprimitia spp.

Remarks: — Some valves of *Conchoprimitia* which do not seem to belong to the species described above have been met with in the Megalaspis Limestone (3cα) and the Asaphus Shale (3cβ). More material is, however, needed to give satisfactory descriptions.

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Manuscript received April 24., 1953.

PLATES 1—2

All specimens except those shown in pl. 1, figs. 2—3 were whitened before photographing. No retouching. Photographer: Miss B. Mauritz.

P.M.O. = Paleontological Museum of the University in Oslo.

R.M. = State Museum of Natural History, Paleozool. Dept., Stockholm.

PLATE 1.

Nanopsis nanella (MOBERG & SEGERBERG, 1906) 54

Fig. 1. Right valve (P.M.O.—1203), c. × 25. — 3aγ, S. Bjerkåsholme, Slemmestad, Røyken.

Rigidella erratica (KRAUSE, 1889) 49

Fig. 2. Left valve (R.M. — Ar. 18690), c. × 20. — Glacial drift boulder, Humlenäs, Kristdala, Småland, Sweden. Coll.:E. Stensiö.
Fig. 3. Same specimen in different light, showing better the convexity of the valve.

Tallinnella primaria (ÖPIK, 1935) 47

Fig. 4. Left valve (P.M.O. — 66390), c. × 25. — 3b, Heramb, Ringsaker. Coll. : S. Skjeseth, 1949.

Glossomorphites lingua (HESSLAND, 1949) 44

Fig. 5. Right valve (P.M.O. — 66420), c. × 26, male type. — 3cβ, N of Slemmestad, Røyken. Coll. : Exc. 1920.

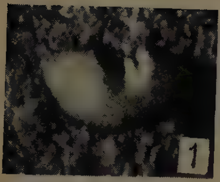
Conchoprimitia eos sp.n. 58

Fig. 6. Interior of right valve (P.M.O. — 66421), c. × 20, showing the two blood canals, one on each side of the adductor muscle scar. — 3b, Heramb, Ringsaker. Coll.: S. Skjeseth, 1949.
Fig. 7. Right valve (Holotype, P.M.O. — 66388), c. × 13. — 3b, Heramb, Ringsaker. Coll. : S. Skjeseth, 1948.

Conchoprimitia socialis vulgaris subsp. n. 61

Fig. 8. Internal mould of right valve (P.M.O. — 66425), c. × 10, showing well the outline of the valve. — 3cβ, Oppijordet, Sandsvær. Coll. : A. Heintz.
Fig. 9. Right valve (P.M.O. — 1834), c. × 10. The muscle scar is faintly visible as a dark, elliptical spot. — 3cβ, Stensberggata in Oslo. Coll.: J. Kiær, 1911.

Plate 1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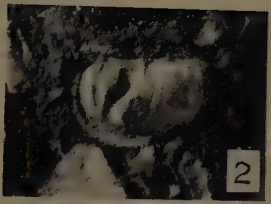
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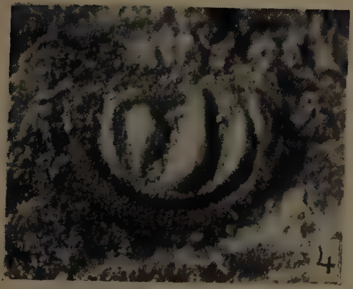
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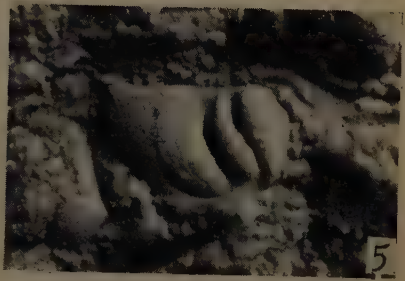
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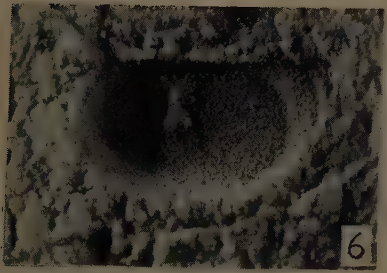
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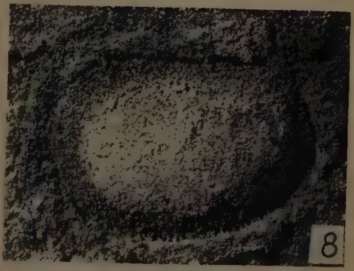
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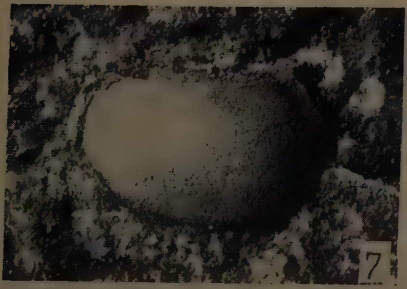
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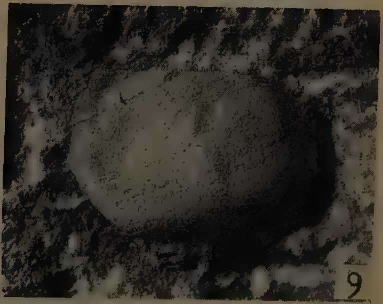
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PLATE 2.

All figures approximately × 10.

Conchoprimitia socialis vulgaris subsp. n. 59

Fig. 1. Left valve (P.M.O. — 1842). Rather large and comparatively low specimen. Sulcoid depression well developed. — 3cβ, Stensberggata in Oslo, Coll. : J. Kiær 1911.

Fig. 2. Internal mould of left valve (P.O.M. — 66423), figured by ÖPIK, 1939 (pl. I, fig. 7). Blood canals are faintly developed. — 3cβ, Krekling, Eiker. Coll. : A. Öpik, 1932.

Fig. 3. Internal mould of right valve (P.M.O. — 2351), showing sulcoid depression, blood canals, and pits. — 3cβ, Ljøterud, Sandsvær. Coll.: T. Strand, 1930.

Fig. 4. Same specimen in different light, showing well the three pits (muscle marks) inside the sulcoid depression.

Fig. 5. Same specimen in different light, showing well the ventral border of the adductor muscle scar.

Fig. 6. Left valve (Holotype, P.M.O. - 66422). The adductor muscle scar is faintly visible. The light-coloured area below it is the shield-like swelling. A curved groove is developed posteriorly. — 3cβ, N of Toje, Røyken. Coll. : L. Størmer exc. 1951.

Conchoprimitia socialis socialis (BRÖGGER, 1882) 61

Fig. 7. Left valve (P.M.O. — 66424). Holotype of *C. broeggeri* ÖPIK, 1939 (pl. 1, fig. 13). — 3cγ, Slemmestad, Røyken. Coll. : A. Öpik, 1932.

Fig. 8. Left valve (Lectotype, P.M.O. — 20212), figured by BRÖGGER 1882, (pl. XII, fig. 14). — 3cγ, Vestfossen, Eiker. Coll. : W. C. Brøgger, 1879.

PLATE 2

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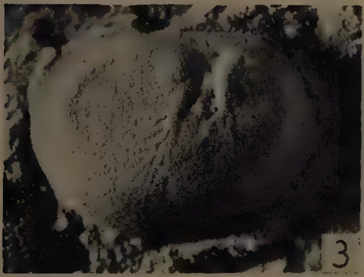
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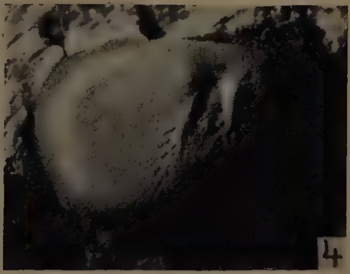
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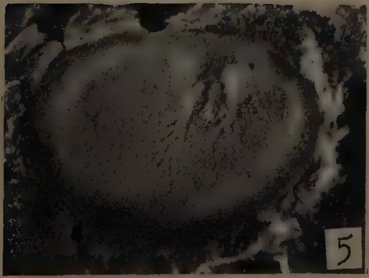
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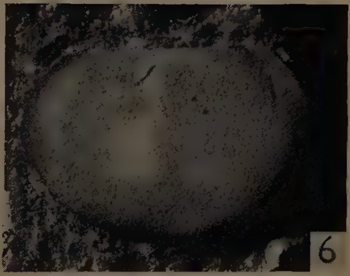
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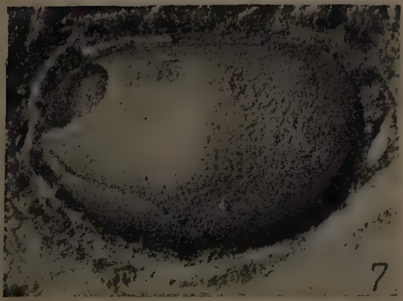
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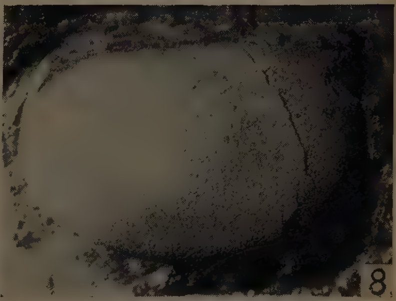
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UPPER ORDOVICIAN OSTRACODS FROM THE OSLO REGION, NORWAY

BY

GUNNAR HENNINGSMOEN
(Paleontological Museum, University of Oslo)

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Abstract. 22 paleocop ostracods are described from the Upper Ordovician of the Oslo Region in Norway. A chart shows their stratigraphical and geographical distribution (p. 101). The following species are new: *Bolbina tuberculata*, *Öpikium porkuniensis*, *Primitia osloensis*, *Platybolbina tiara*, *Laccochilina tarda*, *Bollia accentuata*, *Pseudulrichia norvegica*, and *Monoceratella bos*. The Calcareous Sandstone (5b) is included in the Ordovician, and is placed together with the Gastropod Limestone (5a) in a new division of the Upper Ordovician of the Oslo Region, called the Dalmanitina Series. The underlying Tretaspis Series is restricted to 4c and 4d. Many of the ostracods of the Dalmanitina Series were first described from glacial drift boulders in N. Germany. The fauna resembles that of the Swedish Leptaena Limestone and of the Esthonian Porkuni (Borkholm) Limestone. Some of the drift species are recorded for the first time from in situ material.

Introduction.

The Upper Ordovician is here understood to embrace the Tretaspis Series (4c, 4d) and an overlying series which is here called the Dalmanitina Series (5a, 5b).

Only ostracods belonging to the suborder Paleocopa are described.

The present study is based partly on old collections preserved in the Paleontological Museum, Oslo. These samples were collected primarily because of their macrofossils, and this may explain why ostracods are reported from only two districts in the Oslo Region, and mainly from 5a and 5b. No doubt a systematic searching for ostracods would show that they had a wider geographical distribution and sometimes probably also a greater vertical range than appears from this paper. Most probably also additional forms may be expected to occur. Only in 5b on the Island of Hovedøya, Oslo, have the ostracods been collected for their own sake, namely by the Swedish paleontologist G. Holm in 1877 and by the writer during the present investigation.

The writer would like to express his gratitude to Prof., Dr. E. Stensiö at the Paleozoological Department of the State Museum of Natural History, Stockholm, for placing at his disposal G. Holm's valuable material.

The writer also wishes to thank Prof., Dr. L. Størmer (Paleont. Inst., Oslo) for facilitating this work, and for his interest in it, and cand. real. N. Spjeldnæs for the discussion of certain problems. Furthermore his thanks are due to the Faculty Photographer, Miss B. Mauritz, for photographing the ostracods.

Remarks on the Faunas and the Stratigraphy.

Strangely enough, not a single ostracod has been observed in material from the Tretaspis Beds (4c) and only one species in material from the Isotelus Beds (4d) preserved at the Paleontological Museum. A rich ostracod fauna was, however, found in material of the Gastropod Limestone (5a) and of the Calcareous Sandstone (5b).

The Gastropod Limestone and the Calcareous Sandstone are close to the Ordovician-Silurian boundary, and there is some uncertainty as to where this boundary should be drawn in the Oslo Region. In a paper giving the divisions of stage 4, BRÖGGER (1887) gave the Gastropod Limestone the symbol 4dδ, and included it in the «Lower Silurian» (=Ordovician), whereas the Calcareous Sandstone (referred to as stage 5) was regarded as transitional to the «Upper Silurian» (=Silurian s.s.). In a special paper on these beds, KIÆR (1897, p. 43) changed the symbol of the Gastropod Limestone to 5a, and denoted the Calcareous Sandstone as 5b, the two together forming the stage 5. This was segregated by him (1901, p. 111) as «Middle Silurian» — a separate division between the «Lower Silurian» and «Upper Silurian». In 1934 STØRMER assigned 5a to the Ordovician and 5b to the Silurian, a practice which has been followed by him and other authors in later papers.

The ostracod faunas of 5a and 5b are of an Ordovician type. Many forms are related to those in the Middle Ordovician, but, on the other hand, they contain no members of the Beyrichiidae, so characteristic in the Silurian. The faunas in 5a and 5b are very similar, so, as far as the ostracods are concerned, it would at least be practical to include 5b in the Upper Ordovician.

Cand.real. N. SPJELDNÆS has kindly furnished the writer with some unpublished information on the Ordovician-Silurian boundary sections in the Oslo—Asker district, and this, too, points towards an Ordovician age for 5b.

5b may probably correspond more or less to the Dalmanitina Beds in Sweden. These beds were placed in the Lower Llandovery by WÆRN (1948, p. 465), but O. T. J(ONES) (1949, p. 200) is of the opinion «that in comparison with the British sections the Ordovician-Silurian boundary should be drawn above the Dalmanitina Beds».

For the above-mentioned reasons the writer is inclined to include 5b in the Ordovician.

STØRMER (1953, p. 45) included the Tretaspis Beds (4c), the Isotelus Beds (4d), and the Gastropod Limestone (5a) in the Tretaspis

Series. This series would then correspond to the whole of the Upper Ordovician. When 5b is also placed in the Upper Ordovician, it may be better to divide the Upper Ordovician of the Oslo Region into a lower Tretaspis Series and an upper Dalmanitina Series. It is here suggested that the Dalmanitina Series should embrace 5a and 5b (both containing species of *Dalmanitina*), and to restrict the Tretaspis Series to 4c and 4d.

SILURIAN

UPPER ORDOVICIAN	Dalmanitina Series	5b	Calcareous Sandstone
		5a	Gastropod Limestone
	Tretaspis Series	4d	Isotelus Beds
		4c	Tretaspis Beds

MIDDLE ORDOVICIAN

5a was correlated with the Staurocephalus zone in Sweden by Troedsson (1918, p. 87). This zone has sometimes been classed with the Dalmanitina Beds and sometimes included in the Tretaspis Series (as has been the practice in later years, cf. Wærn, 1948, p. 460). If the Dalmanitina Beds are included in the Ordovician, as suggested by Jones (cf. above), the Staurocephalus zone and the Dalmanitina Beds might again be united in a division, which would correspond to the Dalmanitina Series in the Oslo Region.

The ostracod fauna of the Dalmanitina Series (stage 5) has many genera in common with Middle Ordovician ostracod faunas in the Oslo Region (cf. Henningsmoen, 1953b). It is interesting to note that two N. American genera, not earlier known from Europe, occur in the Dalmanitina Series, namely *Tetradella* (s.s.) known from the Middle Ordovician and the Richmond of the United States, and *Monoceratella*, known from Middle Ordovician rocks in Arctic Canada and N. Greenland.

None of the ostracod species found in the stage 5 fauna seem to have been found outside the Scando-Baltic area, except in Scando-Baltic drift boulders in N. Germany.

Contemporaneous Scando-Baltic Ostracod Faunas.

(Cf. chart p. 101).

Brögger (1887, p. 33) stated that 4bδ (=5a) partly corresponds to the Leptaena Limestone of Sweden and the Lyckholm and Borkholm (=Porkuni) beds of Esthonia. Kiær (1897, p. 52) correlated 5a and 5b with the Lyckholm and Borkholm formation, respectively, Unfortunately the ostracod faunas of the Swedish Leptaena Limestone and the Esthonian Lyckholm and Borkholm formations have not been described from in situ material. Many species have, however. been described from glacial drift boulders in N. Germany, which are claimed to come from these formations. Some of these ostracods have been recognized in the Norwegian material from stage 5.

Sweden.

Two Upper Ordovician ostracod faunas have been described in detail, one from the Tretaspis Beds at Kinnekulle in Vestergötland (Henningsmoen, 1948), and one from the Brachiopod Beds in Scania (Troedsson, 1918). No ostracod fauna contemporaneous with that from the Swedish Tretaspis Beds has been found in Norway. The Brachiopod Beds were correlated with 5b by Troedsson (1918, p. 87). Only one of its 12 ostracod species, *Primitiella? rara* (Troedsson, 1918), may occur in 5b in the Oslo Region. The difference in the ostracod faunas may be due to a difference in facies; the Brachiopod Beds are developed as shale while 5b is developed as calcareous sandstone, sandy limestone or conglomerate.

Several of the N. German drift boulder species have been specially stated to occur in boulders of Leptaena Limestone, namely four forms described by Steusloff (1894); *Leperditia krausei* (?=*Macronotella praelonga*), *Leperditia*? *kiesowii* (?= *Macronotella praelonga*), *Isochilina frequens* (here = *Öpikella frequens*), *Primitia elongata semicircularis* (?= *Platybolbina plana*), and several additional forms described or listed by Kummerow (1924); *Leperditia phaseolus praecursor* Kummerow, 1924, *Primitiella* (?) *kuckersiana* Bonnema, 1909 (the occurrence of this Middle Ordovician species in Leptaena Limestone appears doubtful), *Primitia*(?) *bursa* Krause, 1889, *Primitia distans* Krause, 1889 (?= *Platybolbina plana*), *Primitia parva* Kummerow, 1924 (probably not a *Primitia* species), *Primitia plana*

KRAUSE, 1889 (here = *Platybolbina plana*), *Craspedobolbina dietrichi* KUMMEROW, 1924, *Kloedenia globosa* KRAUSE, 1889 (probably not a *Kloedenia* species), *Bollia granulosa* KRAUSE, 1889 (possibly a *Primitia* species), and *Macronotella lenticularis* KUMMEROW, 1924.

Some of these forms have been recognized in the Norwegian material from stage 5. If the above-mentioned drift species really come from Leptaena Limestone, this agrees with the general view that the stage 5 is more or less contemporaneous with a part of the Leptaena Limestone.

Scando-baltic drift boulders in N. Germany.

Besides the above-mentioned drift species, assumed to occur in Leptaena Limestone and Porkuni (Borkholm) Limestone, or recognized in in situ material of Porkuni Limestone, there are others which have been observed in the stage 5 fauna, and thus for the first time recorded from material collected in situ. The age of these forms has hitherto been uncertain, but it may now be regarded as late Upper Ordovician. These species are: *Bollia duplex* KRAUSE, 1892 and (described from the same boulder) *Primitia* (*Ulrichia*?) *umbonata* KRAUSE, 1892 (here = *Platybolbina umbonata*). In addition, *Primitia elongata* KRAUSE, 1891 (here = *Platybolbina elongata*) and *Primitiella umbilicata* KUMMEROW, 1924 (here = *Öpikella umbilicata*) may probably be present in the Norwegian material.

Several of the ostracods in the stage 5 fauna were listed by KUMMEROW (1924) as occurring also in drift boulders of a type referred to as «Algenkalk». This may thus be of late Upper Ordovician age. Some species listed from this by KUMMEROW were not recognized in the stage 5 fauna, but may be expected in beds of this age, namely *Aparchites marchicus* KUMMEROW, 1924, *A. cuneatus* KUMMEROW, 1924, *Primitia corrugata* KRAUSE, 1892 (not a *Primitia* species), and *Macronotella lenticularis* KUMMEROW, 1924.

Esthonia.

In his paper on ostracods from the Middle Ordovician Uhaku and Kukruse formations, ÖPIK (1937) described or mentioned also a few species from Upper Ordovician formations, namely *Piretella acmaea* ÖPIK, 1937 and an unnamed *Uhakiella* species (l.c., p. 42) (perhaps *Primitia osloensis* sp. n.) from the Lyckholm formation, and *Biflabellum flabelliferum* (KRAUSE, 1892) (here = *Öpikium porkuniensis* sp. n.) from the Porkuni (=Borkholm) formation. KRAUSE (1892, p. 398, foot-note) recorded the following species from the Porkuni formation at Porkuni: *Beyrichia dissecta* KRAUSE, 1892 (here = *Kiesowia dissecta*), *Beyrichia plicata* (error for *plicatula*) KRAUSE, 1892 (here = *Tetradella plicatula*), *Primitia elongata* KRAUSE, 1892 (here = *Platybolbina elongata*), *Primitia distans* KRAUSE, 1889 (here = *Platybolbina distans*), and an *Isochilina* species (=*Öpikella frequens*, cf. STEUSLOFF, 1894, p. 783). The following three forms are present in material from the Porkuni formation at Porkuni, preserved at the Paleontological Museum in Oslo: *Kiesowia dissecta, Platybolbina elongata,* and *Platybolbina distans.*

STEUSLOFF (1894) mentioned the following ostracods from a sample, which, on lithological and faunal (ostracods) evidence, he believed to be the Borkholm Limestone: *Primitia jonesii* KRAUSE, 1889 (here = *Chilobolbina? jonesiana* (SCHMIDT, 1941)), *Primitia plana* (here = *Platybolbina plana*), *Primitia distans* (? = *Platybolbina plana*), and described the following ostracods: *Leperditia praelonga* (here = *Macronotella praelonga*), *Primitia cuneata* (= *Steusloffina cuneata*, a bairdiid), *Primitia rugosa* (probably not a *Primitia*), *Primitia canaliculata* (probably not a *Primitia*), and *Primitia elongata obliqua* (? = *Platybolbina plana*).

The Porkuni fauna thus agrees rather well with that of stage 5 in the Oslo Region.

Systematic descriptions.

Only paleocop ostracods are described in the present paper. Non-paleocop ostracods also occur in the Upper Ordovician of the Oslo Region, e.g. *Steusloffina cuneata* (STEUSLOFF, 1894), which has been met with in 5b. No doubt even more paleocop ostracods will be found later. A few defective valves, not belonging to any of the species described below, were observed in 5b.

An interrogation mark in front of the name of a systematic unit indicates that it is uncertain whether it really belongs to the next higher taxonomic unit.

Suborder PALEOCOPA HENNINGSMOEN, 1953
Superfamily Beyrichiacea ULRICH & BASSLER, 1923
Family Sigmoopsiidae HENNINGSMOEN, 1953
Subfamily Sigmoopsiinae HENNINGSMOEN, 1953
Genus *Sigmobolbina* HENNINGSMOEN, 1953

Type species: — By original designation, *Entomis oblonga* var. *Kuckersiana*, BONNEMA, 1909.

Sigmobolbina? sp.

(Pl. 1, figs. 1—2; text fig. 1.)

Material: — A few valves, preserved in limestone.

Description: — The valves reach a size of about 0.9 × 0.5 mm. Slight forward swing. Unisulcate; sulcus somewhat sigmoidal, deep behind faint presulcate node, rather shallow and faint ventrally. No flanges, but a submarginal bend separates the lateral and marginal surface anteriorly and ventrally. A short, broad-based, spurlike spine is developed postero-ventrally. The lateral surface slightly overhangs the free margin ventrally. Surface smooth.

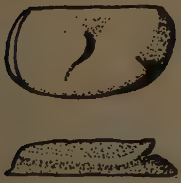
Fig. 1. *Sigmobolbina*? sp. Lateral and ventral view of left valve (reconstruction). x 20.

Remarks: — This form resembles *Sigmobolbina obliqua* (KRAUSE, 1892), and may possibly belong to the same genus. No dimorphism was observed in the present form, but this may be due to lack of sufficient material. It probably represents a new species, but more material is needed to give an adequate description.

Occurrence: — Oslo—Asker (5b, Hovedøya).

Genus *Bolbina* HENNINGSMOEN, 1953

Type species: — By original designation, *Bollia ornata* KRAUSE, 1892.

Bolbina aff. *minor* (KRAUSE, 1892)

(Pl. 1, fig. 13.)

Remarks: — One single valve, 0.7 mm long and 0.4 mm high, resembles the Middle Ordovician species *Bolbina minor*. The valve is, however, not too well preserved.

Occurrence: — Oslo—Asker (5b, Hovedøya).

Bolbina tuberculata sp.n.

(Pl. 1, figs. 3—5; text fig. 2.)

Name: — The name *tuberculata* alludes to the tuberculate surface.

Type data: — Holotype (P.M.O. — 66428a) is a left valve from 5b at Hovedøya in Oslo.

Material: — 10 separate valves, all preserved in limestone.

Diagnosis: — A small *Bolbina* species with a presulcal node and a postero-ventral lobe-like node. The nodes are separated by the sulcus, not united as usual in *Bolbina*. Surface tuberculate.

Description: — The valves reach a size of about 0.7 × 0.4 mm. Slight forward swing. Unisulcate; sulcus poorly developed dorsally, forms a deep, characteristic pit just behind the round presulcate node, and is fairly well developed ventrally. Behind the ventral part of the sulcus there is an elongate, oblique lobe-like node. A narrow velate frill is developed parallel to the ventral and lower half of the anterior border. Surface ornamented with comparatively large tubercles.

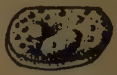

Fig. 2. *Bolbina tuberculata* sp. n. Left valve (reconstruction). x 20

Remarks: — *Bolbina tuberculata* resembles species like *B. ornata* (Krause, 1896), but differs in being tuberculate, and in having the sulcus prolonged ventrally, thus separating the presulcal node and the postero-ventral lobe-like node. Nevertheless, it seems reasonable to include the present species in *Bolbina*. No dimorphism was observed in *B. tuberculata*.

Occurrence: — Oslo—Asker (5b, Hovedøya).

?Genus *Kiesowia* Ulrich & Bassler, 1908.

Type species: — By original designation, *Beyrichia dissecta* Krause, 1892.

Kiesowia dissecta (Krause, 1892)

(Pl. 2, figs. 1—3, 5.)

1892 *Beyrichia dissecta* n.sp. — Krause, p. 392, pl. XXI, fig. 3.

?1892 *Beyrichia mamillosa* n.sp. — KRAUSE, p. 393, pl. XXII, fig. 14.
1894 *Tetradella? dissecta* (KRAUSE) — ULRICH, p. 679.
?1894 *Tetradella? mamillosa* (KRAUSE) — ULRICH, p. 679.
1908 *Tetradella (Kiesowia) dissecta* (KRAUSE) — ULRICH, p. 306, pl. 39, fig. 10.
?1908 *Tetradella (Kiesowia) mamillosa* (KRAUSE) — ULRICH, p. 306, pl. 39, fig. 11.
1923 *Kiesowia dissecta* (KRAUSE) — ULRICH & BASSLER, pp. 310, 311, text fig. 20 (fig. 6).
1934 *Kiesowia dissecta* (KRAUSE) — BASSLER & KELLETT, p. 349.
?1934 *Kiesowia mamillosa* (KRAUSE) — BASSLER & KELLETT, p. 349.
1937 *Kiescwia dissecta* (KRAUSE) — ÖPIK, p. 31.
?1937 *Kiesowia mammilosa* (KRAUSE) — ÖPIK, p. 31.
1951 *Kiesowia dissecta* (KRAUSE) — KESLING, p. 158, pl. V, fig. 3.
?1951 *Kiesowia mamillosa* (KRAUSE) — KESLING, p. 157, pl. IV. fig. 3.
1953 *Kiesowia dissecta* (KRAUSE) — HENNINGSMOEN, p. 210.
?1953 *Kiesowia mammilosa* (KRAUSE) — HENNINGSMOEN, p. 210.

Type data: — As lectotype is here chosen the right valve figured by KRAUSE (1892, pl. XXI, fig. 3) from a glacial drift boulder at Müggelheim, N. Germany.

Present material: — About 10 valves and internal moulds of valves, preserved in limestone.

Description of present material: — Adult valves about 1.9 mm long and 1.1 mm high. Elongate, with slight forward swing. Tetralobate. L2 developed as a rather round node. L1, L3, and L4 are all divided into two nodes. L1 tends, however, to split into three nodes. This is especially seen in larval valves. The dorsal node(s) of L1 is (are) round and rather small; its ventral node is also round, but larger. The dorsal nodes of L3 and L4 are round, whereas their ventral nodes are elongate. S1 is short, S2 and S3 long. S2 is best developed; it is deepest just behind L2. A fairly well developed velate frill is preserved in two specimens. It is restricted to the anterior and ventral border areas and appears to be replaced by a row of spines posteriorly. The frill is radially striate, as if composed of fused spines. The frill is very faintly convex in both specimens. It narrows upwards along the anterior border, and dies out before it reaches the dorsal border, whereas it ends rather abruptly posteriorly. The surface of the valve between the lobes is reticulate (or granuloreticulate), whereas the surface of the nodes, especially L2, L3, and L4, appears smoother. The nodes are, however, covered by scattered, relatively large tubercles.

Remarks: — No frill was described by KRAUSE; instead his figure of the lectotype shows a submarginal row of tubercles. The same feature is seen in internal moulds of the present material. It is thus possible that his specimen is an internal mould, or it may represent the male type, if the two present specimens with velate frill represent the female type. *Kiesowia mamillosa* (KRAUSE, 1892) agrees rather well with larval forms of *K. dissecta* and may probably be a synonym.

Occurrence: — Oslo—Asker (5a-b, Nedre Ås in Bærum; 5b, Hovedøya), Ringerike (5a, Stavnestangen). — Esthonia (Porkuni Limestone, Porkuni), N. Germany (glacial drift boulders).

Family Tetradellidae SWARTZ, 1936

Subfamily Tetradellinae SWARTZ, 1936

Genus *Tetradella* ULRICH, 1890.

Type species: — *Beyrichia quadrilirata* HALL & WHITFIELD, 1875, by subsequent designation of ULRICH (1894, p. 677).

Remarks: — The genus *Tetradella* was restricted by HENNINGSMOEN (1953, p. 213) to the *Tetradella quadrilirata* group only, i.e. to those species which develop submarginal loculi.

Tetradella plicatula (KRAUSE, 1892)

(Pl. 1, figs. 8—11; text fig. 3.)

1892 *Beyrichia plicatula* sp.n. — KRAUSE, pp. 394, 399, pl. XXII, fig. 13.
1892 *B(eyrichia) plicata* sp.n. [error for *B. plicatula* sp.n.:] — KRAUSE, p. 398.
1934 *Bollia? plicatula* (KRAUSE) — BASSLER & KELLETT, p. 218.

Type data: — Holotype is the left valve figured by KRAUSE (1892). It was stated to come from a drift boulder of uncertain age in N. Germany. In a list KRAUSE (p. 399) tentatively assigned it to the Upper Silurian (=Silurian s.s.). BASSLER & KELLETT (1934) stated that the drift is a *Ceratopsis rostrata* limestone (Lower Ordovician). This appears to be a mistake, probably due to the fact that many of the other species described in the same paper (KRAUSE, 1892) came from drift of this limestone. The lithological character of the boulder (according to KRAUSE's description) suggests that it may be Porkuni Limestone. Furthermore KRAUSE (p. 398) reported it (by mistake as *B. plicata*) from a sample of Borkholm (=Porkuni) Limestone from Esthonia. It thus appears rather probable that the holotype also came from beds of this age.

Present material: — 8 more or less damaged valves, all preserved in limestone.

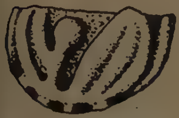

Fig. 3. *Tetradella plicatula* (KRAUSE). Left valve of female type (reconstruction) x 16.

Description of present material: — The valves are up to about 1.1 mm long and 0.7 mm high. Slight forward swing. Surface traversed by several ridges. Disregarding these, the main surface of the valve is trilobate. The anterior lobe (L1) carries two longitudinal ridges. The median lobe (L2) is developed as a round node, continuing ventrally in a ridge which after a short distance unites with the inner ridge of L1. Whereas S1 is short, S2 is long and well developed. The posterior lobe (L3 + L4) carries three longitudinal ridges. The two outer ones are ventrally connected with the outer ridge of L1, thus forming a carinal ridge. The remaining ridges unite ventrally with the carinal ridge. An entire velate ridge is also present. A row of loculi are developed between the velate and the carinal ridge in some specimens (female type). The material is not good enough to show exactly how many loculi are developed, but there appear to be five. The surface appears smooth.

Remarks: — The present specimens agree well with *T. plicatula* in the number and arrangement of ridges, and may be considered conspecific. No subventral loculi are described in the holotype, which apparently is of the male type. *T. plicatula* appears to be the only known European form referable to *Tetradella* (s.s.). It comes rather close to *T. ulrichi* described by KAY (1934, p. 339) from the Middle Ordovician Hull, Decorah, and Sherman Fall formations in U. S. A., but this differs from *T. plicatula* inter alia in that the inner anterior ridge and the ridges below the median node do not unite ventrally.

Occurrence: — Oslo—Asker (5a-b, Nedre Ås in Bærum; 5a, Hovedøya) — N. Germany (drift boulders), Esthonia (Porkuni Limestone, Porkuni).

?Subfamily Piretellinae Öpik, 1937

?Genus *Öpikium* Agnew, 1942

Type species: — *Biflabellum tenerum* Öpik, 1935a (probably a synonym of *Entomis flabellifera* Krause, 1892, cf. below).

Öpikium porkuniensis sp. n.

(Pl. 2, fig. 4.)

1937 *Biflabellum flabelliferum* Krause (partim) — Öpik, p. 39, pl. V, fig. 8.

Name: — From Porkuni (=Borkholm) in Esthonia.

Type data: — As holotype is chosen the specimen figured by Öpik (1937, pl. V, fig. 8) as *Biflabellum flabelliferum* from the Porkuni (=Borkholm) formation at Porkuni in Esthonia.

Remarks: — Öpik (1937, p. 39) identified an Upper Ordovician (Porkuni formation) species as *Öpikium* (=*Biflabellum*) *flabelliferum*, a species described from a glacial drift boulder in N. Germany by Krause (1892, p. 388) as *Entomis* (*Primitia*?) *flabellifera*. The drift species is, however, a Middle Ordovician form, as can be ascertained by the associated fauna, an *Öpikella* («*Isochilina*«) *canaliculata* fauna (cf. Andersson, 1893). Its very wide frill makes it probable that *Öpikium tenerum* (Öpik, 1935a) from the Middle Ordovician Kukruse formation is a junior synonym. Some specimens described by Bonnema (1909, p. 70) were, probably correctly, referred by him to *Entomis flabellifera*. They were, however, transferred to *Biflabellum tenerum* by Öpik (1937, p. 40).

The form from the Porkuni formation is not *Ö. flabelliferum*. It is described below as a new species, *Ö. porkuniensis*.

Diagnosis: — An *Öpikium* species with very wide velate frill. The frill may be as wide as the valve proper is high, whereas in the also wide-frilled *Ö. biflabellum* (and *Ö. tenerum*) the frill may be markedly wider than the valve proper is high. The frill is finely radially striate in *Ö. porkunensis* sp.n., whereas it is coarsely radially striate in *Ö. biflabellum* (and *Ö. tenerum*).

Description of holotype, based on figure given by Öpik (1937, pl. V, fig. 8): — Ends subequal. Unisulcate; sulcus (S2) long, with geniculum. Just in front of the bend of the sulcus there is a small node-like inflation, corresponding to L2. A velate frill is developed in the anterior and ventral border areas. It does not reach the dorsal border anteriorly. It widens posteriorly and ends abruptly. Its maximum width is about as great as the height of the valve proper (excluding frill). The frill is finelly radially striate, and shows also very fine concentric structures. The frill is somewhat incurved, especially along the border. The specimen is thus of the female type. The specimen (including frill) is about 2.9 mm long and 1.8 mm high.

Present material: — A right valve (female type, 3.3 × 2.0 mm) and a few impressions (male type), preserved in limestone. The female type agrees very well with the holotype. The impressions of male type valves are not good, and do no allow a detailed description. The frill is apparently not as wide as in the female type, and not incurved.

Occurrence: — Oslo—Asker (5b, Hovedøya), Ringerike (5a, Stavnestangen) — Esthonia (Porkuni).

Family Primitiidae Ulrich & Bassler, 1923.
Genus *Primitia* Jones & Holl, 1923

Type species: — *Beyrichia strangulata* McCoy, 1851 (designated by Miller, 1889).

Primitia osloensis sp. n.

(Pl. 1, figs. 6—7.)

Type data: — Holotype is a left valve (P.M.O. — 55 081a) from 5a, Stavnestangen, Ringerike.

Material: — A few valves of the female type, preserved in limestone.

Diagnosis: — A small *Primitia* species with short velate pouch (about 3/5 length of valve) and granulate surface.

Description: — Adult valves about 1.1 mm long and 0.7 mm high, disregarding velate pouch. Slight forward swing. Sulcus rather faint; presulcal node small. The velate pouch has an antero-ventral position, and is rather short, about 3/5 the length of the valve. It is faintly and irregularly striate. Surface of valve is granulate.

Remarks: — In size this species recalls *Primitia* («*Uhakiella*») *pumila* (Öpik, 1937) from the Middle Ordovician of Esthonia, which, however, has the pouch situated more anteriorly. *P. osloensis* sp.n. also reminds one of *P. strangulata*, which is larger and has a longer pouch. ÖPIK (1937, p. 42) mentions an undescribed *Uhakiella* species from the Lyckholm formation in Esthonia. It may possibly be *P. osloensis*.

Occurrence: — Oslo—Asker (5b, Hovedøya), Ringerike (5a, Stavnestangen).

Genus *Chilobolbina* ULRICH & BASSLER, 1923

Type species: — By original designation, *Primitia dentifera* BONNEMA, 1909.

Chilobolbina? cf. *jonesiana* (SCHMIDT, 1941)

(Pl. 6, fig. 5; text fig. 4.)

cf. 1889 *Primitia Jonesii* n.sp. — KRAUSE, p. 8, pl. I, fig. 6.
cf. 1934 *Primitia jonesii* (KRAUSE) — BASSLER & KELLETT, p. 446.
cf. 1941 *Mirochilina jonesiana* n. nom. — SCHMIDT, p. 29 (not pl. 3, figs. 20—23.)

Type data: — Holotype (by monotypy) is the left valve figured by KRAUSE (1889) from a drift boulder of unknown age in N. Germany.

Present material: — Some 25 valves, preserved in limestone.

Description of present material: — Adult valves about 2.0 mm long and 1.4 mm high. Ends subequal, cardinal angles obtuse. Moderately and rather evenly convex save for the one sulcus (S2). The sulcus is short, and almost as well defined dorsally as ventrally; thus having a sausage-like outline. The valve is very faintly swollen around the sulcus. A dorsal plica (ridge) is developed both in front of and behind the sulcal area. A slightly oblique row of spines is developed behind the sulcus, and is connected with the anterior end of the posterior dorsal plica. A submarginal row of spines appears to represent the velate structure. Inside this row, there is another subparallel row of spines. The surface of the valve is densely covered with granules; in between there are a few larger ones (probably spine bases).

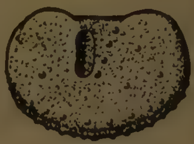
Fig. 4. *Chilobolbina*? cf. *jonesiana* (SCHMIDT). Left valve (reconstruction). x 12.

Remarks: – The drawing given by KRAUSE (1889) of the holotype differs from the present material in having the sulcus more centrally placed. Apart from this the present material agrees very well with KRAUSE's figure and description of *Primitia Jonesii*, and may well be conspecific. Two specimens described by KRAUSE (1891, p. 493, pl. XXXI figs. 6, 7) as *Primitia* aff. *Jonesii* differ from this species in many features (also in developing a dimorphic pouch?) and does not seem to be closely related. Probably these specimens belong to a *Primitia* species. SCHMIDT (1941, p. 29) pointed out that *Primitia Jonesii* KRAUSE, 1889 is a synonym of *P. Jonesii* KONINCK, 1876, and gives the new name *jonesiana* to KRAUSE's form. At the same time SCHMIDT changes the generic reference to *Mirochilina*. This genus (with two species) was described from the Ludlow in Bohemia by BOUČEK (1936). However, it seems rather questionable if *jonesiana* should be assigned to *Mirochilina*. On the other hand *jonesiana* agrees rather well with some forms assigned to *Chilobolbina*, cf. for example *Chilobolbina decumana* (BONNEMA) as figured by BONNEMA (1909, pl. II, fig. 12). This specimen has a similar sulcus, dorsal plicae, and type of ornamentation, but differs inter alia in having a velate frill. Quite possibly *jonesiana* represents an offshoot which does not develop a dimorphic frill. SCHMIDT further assigns some Caradoc specimens from Bohemia to *jonesiana*. These seem to differ from *jonesiana* inter alia in developing a velate frill (at least in some specimens), and it is possible that they represent another species congeneric with *jonesiana*.

Occurrence: — Oslo—Asker (5b, Hovedøya; 5a-b, Nedre Ås in Bærum) — N. Germany (drift).

Family Eurychilinidae ULRICH & BASSLER, 1923

Subfamily Eurychilininae ULRICH & BASSLER, 1923

Genus *Platybolbina* HENNINGSMOEN, 1953b

Type species: — By original designation, *Primitia distans* KRAUSE, 1889.

Remarks on the generic name: — *Primitia distans* was referred to as *Platychilina distans* by KUMMEROW (1933). He gave, however, no definition of the genus, and designated no type species. This was later done by THORSLUND (1940 p. 169), who selected *Primitia distans*

KRAUSE, 1889 as type species. Meanwhile, KUMMEROW (1939, p. 19) had already given a definition of the genus, and designated *Primitia elongata* KRAUSE, 1891 as type species. As pointed out by AGNEW (1944, p. 219) the ostracod genus *Platychilina* is a junior homonym of the gastropod genus *Platychilina* KOKEN, 1892. The new name *Platybolbina* was suggested for the ostracod genus by HENNINGSMOEN (1953b, p. 50), who unfortunately was not aware of KUMMEROW's erection of the genus in 1939[1].

Platybolbina was therefore proposed as a new name for *Platychilina* THORSLUND, 1940, with *P. distans* as type. For this reason it may be correct to regard *P. distans* as type species of *Platybolbina*, and not *P. elongata*. Fortunately *P. distans* and *P. elongata* appear to be congeneric.

Remarks on the type species: — *Primitia distans* was first described by KRAUSE (1889, p. 6) from a N. German glacial drift boulder, which was listed by KUMMEROW (1924) as Leptaena Limestone. In 1892 KRAUSE (p. 386, pl. XXI, fig. 16) assigned another drift boulder specimen to *P. distans*. The age of this boulder can now safely be regarded as late Upper Ordovician, since *Bollia duplex* and *Platybolbina umbonata* occur in it, and these two characteristic species are recorded from the late Upper Ordovician in Norway.

In 1896 KRAUSE (p. 933, pl. XXV, figs. 7—8) reported *P. distans* from a Middle Ordovician glacial drift boulder from Holland. BONNEMA (1909, p. 29) erected a new species, *P. kapteyni*, for the Middle Ordovician form, which he also described from Esthonian material from the Middle Ordovician Kukruse (Kuckers) beds. According to BONNEMA the difference between the Middle Ordovician *Primitia kapteyni* and the Upper Ordovician *P. distans* should be that whereas *P. kapteyni* showed a reticulate surface pattern (save for a smooth muscle spot, a smooth triangular area at the anterior cardinal angles, and a smaller smooth triangular area at the posterior cardinal angle), *P. distans* had a granulated surface (save for the muscle spot). He had, at hand, material of *P. distans* from the Upper Ordovician of Esthonia, and could not find any specimens with reticulate pattern in it. He therefore confidently assigned the specimen of *P. distans* (showing a reticulate pattern) described by KRAUSE (1892) to *P. kapteyni*. It is now known that this specimen is of Upper Ordovician age. Furthermore the writer has observed specimens of *P. distans* with reticulate surface pattern in material of the late Upper Ordovician Porkuni (Borkholm) formation in Esthonia. It therefore seems that the reticulation cannot be used to distinguish these two species. The problem is further complicated by the description of quite smooth specimens of *P. kapteyni* from the Middle Ordovician of Sweden by THORSLUND (1940, p. 169) — only in one specimen a distinct but minute reticulation was observed.

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[1] The writer wishes to thank Prof., Dr. HENRY V. HOWE (Louisiania State University) for bringing this paper to his attention.

It is possible that *P. kapteyni* should be regarded as a synonym of *P. distans*, but the rather great difference of age between them seems to make this less probable. Both species sometimes appear to show a reticulate pattern. The type specimen of *P. distans* was stated by KRAUSE to be granulate. However, internal moulds of *P. kapteyni* (described by KRAUSE, 1896 as *P. distans*) are also granulate, and it is thus possible that the type specimen of *P. distans* is also an internal mould. As suggested by KRAUSE (1896, p. 933) the reticulate pattern is probably due to the prismatic layer of the shell. It is important, as pointed out by KUMMEROW (1933, p. 44), that the reticulate pattern may be seen *through* the exterior shell layer in favourably preserved specimens, whereas otherwise this pattern is first seen when the exterior shell layer has weathered away. It is possible that *P. distans* differs from *P. kapteyni* in having a more acute posterior end. Better material is, however, needed to ascertain possible differences between these two species.

Primitia elongata semicircularis STEUSLOFF (1894) is probably a synonym of *P. distans*. It is possible that *Platybolbina distans* is a synonym of *P. plana*, as discussed below.

Platybolbina cf. *plana* (KRAUSE, 1889)

(Pl. 3, figs. 1—8.)

cf. 1889 *Primitia plana* n.sp. — KRAUSE, p. 5, pl. I, figs. 1a—b.
?1889 *Primitia distans* n.sp. — KRAUSE, p. 6, pl. I, figs. 3a-b.
?1892 *Primitia distans* KRAUSE — KRAUSE, pp. 386,398, pl. XXI, fig. 16.
?1894 *Primitia elongata* var. *obliqua* n. v. — STEUSLOFF, p. 783, pl. LVIII, fig. 12.

?1894 *Primitia elongata* var. *semicircularis* n.v. — STEUSLOFF, p. 784, pl. LVIII, fig. 13.
?1909 *Primitia distans* KRAUSE — BONNEMA, p. 30.
cf. 1923 *Apatochilina plana* (KRAUSE) — ULRICH & BASSLER, p. 521.
?1923 *Coelochilina distans* (KRAUSE) — ULRICH & BASSLER, p. 421.
cf. 1924 *Primitia plana* KR. — KUMMEROV, p. 440.
?1924 *Primitia distans* KR. — KUMMEROW, p. 440.
?1933 *Platychilina* (=*Primitia*) *distans* (KR.) — KUMMEROW, p. 44.
cf. 1934 *Apatochilina plana* (KRAUSE) — BASSLER & KELLETT, p. 162.
?1934 *Coelochilina distans* (KRAUSE) — BASSLER & KELLETT, p. 246.
?1934 *Primitia? elongata semicircularis* STEUSLOFF — BASSLER & KELLETT, p. 443.
?1934 *Primitia* (*?Eurychilina*) *elongata obliqua* STEUSLOFF — BASSLER & KELLETT, p. 443.
?1940 *Platychilina distans* (KRAUSE) — THORSLUND, p. 169.
?1953b *Platybolbina distans* (KRAUSE) — HENNINGSMOEN, p. 50.

Type data: — *Platybolbina plana* was founded upon a single specimen (holotype), which was described from a glacial drift boulder in N. Germany. It was associated with the holotype of *Platybolbina distans*. The boulder was stated by KUMMEROW (1924, p. 440) to be of Upper Ordovician (Leptaena Limestone) age.

Present material: — A great number of separate valves (including larval instars) preserved in limestone.

Description of present material: — Adult valves up to about 2.0 mm long and 1.1 mm high. Moderately convex; convexity somewhat varying. Faint forward swing. Anterior cardinal angle slightly obtuse or slightly acute. Posterior cardinal angle slightly acute. Each cardinal angle may protrude into a spinelike point, especially in larval valves. Non-sulcate, but a very faint and diffuse sulcoid depression may occasionally be distinguished. An elliptical subcentral muscle spot is often discernible, especially on internal moulds. Velate structure developed as a frill in the ventral and greater part of the anterior border area. It is widest anteroventrally, and tapers towards both ends, from where it continues in a velate ridge, reaching the dorsal margin at both ends. In larval moults and in adult valves of the male type the frill is flat, and rises up from the sagittal plane of the carapace. It is radially striate, but the striae do not always quite reach the edge of the frill. In valves of the female type the frill is more or less convex, and often twice as wide as in the male type. The radial striae are sometimes not discernible in the valves of female valves.

The surface ornamentation is variable. In larval moults the surface is usually pitted (save for the muscle scar), but is often smooth or finely granulate. In valves of the female type the surface is usually smooth but may be finely granulate, or, rarely, pitted. A reticulate pattern described by KRAUSE (1892) in *P. distans* and seen by the author in Esthonian material of the same species, has not been observed in the Norwegian material. This is perhaps because the Norwegian material is preserved in dark, unweathered limestone. Such reticulation is usually seen when the valves are translucent (as sometimes in light-coloured limestones) or when the valve is weathered (cf. above).

Remarks: — This appears to be a rather variable species, both in outline and surface ornamentation. Some of the valves in the Norwegian material agree rather well with the holotype of *Platybolbina plana*, and others with the holotype of *P. distans*. As intermediate types occur as well, it appears possible that both forms belong to one species. The writer has not had the opportunity to examine the type material but it may be recalled, however, that the two holotypes occur in the same glacial drift boulder. It also appears probable that *Primitia elongata obliqua* STEUSLOFF, 1894 and *P. elongata semicircularis* STEUSLOFF, 1894 belong to the same species. They were stated to come from boulders of Porkuni Limestone and Leptaena Limestone, respectively.

Occurrence: — Oslo—Asker (5a, Bærum; 5a, Asker; 5b, Hovedøya; 5b, Sandviksåsen), Ringerike (5a, Stavnestangen; 5a Frognøy) — Esthonia (Porkuni Limestone, Porkuni), N. Germany (glacial drift boulders).

Platybolbina tiara sp.n.

(Pl. 4, figs. 4—9.)

Name: — The name alludes to the rather fine, tiara-like frill of this species.

Type data: — The holotype (P. O. M. — 66434) is a left valve from 5b at Hovedøya, Oslo.

Diagnosis: — A *Platybolbina* species with entire, rather coarsely striate, velate frill (showing dimorphism), a short sulcus, and a poorly defined node in front of it. Surface pitted and granulate.

Description: — Adult valves reach a length of about 1.9 mm and height of about 1.2 mm. Moderately convex; rather slight forward swing. Unisulcate. The sulcus is short, and not well defined dorsally. It is deepest in its ventral end, just behind and below a poorly defined node. Velate frill entire, i.e. reaching from anterior to posterior dorsal angle. The frill has coarse, radially arranged striae, and shows also some very fine concentric wrinkles. The frill is flat and narrow or wide in valves of the male type, and convex and wide in valves of the female type. The surface is rather coarsely pitted and granulate.

Affinities: — This characteristic species recalls *P. umbonata*, but differs in not having such a large node, in showing velate dimorphism and in attaining a greater size. *P. tiara* sp.n. differs from *P. plana* inter alia in having an entire frill.

Occurrence: — Oslo—Asker (5b, Hovedøya).

Platybolbina cf. *elongata* (KRAUSE, 1891)

(Pl. 1, fig. 14.)

cf. 1891 *Primitia elongata* n.sp. — KRAUSE, p. 494, pl. XXX, figs. 4a-b.
1892 *Primitia elongata* KRAUSE — KRAUSE, p. 386, pl. XXII, fig. 2.
cf. 1924 *Primitia elongata* KR. — KUMMEROW, pp. 409, 440.
cf. 1934 *Primitiella elongata* (KRAUSE) — BASSLER & KELLETT, p. 461.
cf. 1939 *Platychilina elongata* (KRAUSE) — KRAUSE, p. 19.
1948 *Platychilina* (=*Primitia*) *elongata* (KR.) — KUMMEROW, p. 20, text fig. 5.
(non 1896 *Primitia elongata* KRAUSE — KRAUSE, p. 933, pl. 25, fig. 9.)

Type data: — Holotype (by monotypy) is the left valve figured by KRAUSE (1891) from a glacial drift boulder in N. Germany.

Present material: — About 15 valves preserved in limestone.

Description of present material: — Elongate, largest valve about 1.4 mm long and 0.7 mm high. Slight forward swing. In some specimens a short, narrow and poorly defined sulcus is present, in front of which is then a small, not well defined node. In other specimens the sulcus and node are missing or are only faintly visible. An elliptical muscle scar is usually seen ventral to the sulcus. The scar is smooth, whereas the surface of the valve is elsewhere rather coarsely granulate. The velate frill is entire, flat and radially striate. It is rather narrow (male type) or rather wide (female type).

Remarks: — The present material agrees very well with the specimen (female type) described by KRAUSE in 1892. It is, however, uncertain whether the holotype is conspecific with this form or with the Middle Ordovician form assigned to *P. elongata* by KRAUSE in 1896. For this reason it appears best to refer to the present material as *P.* cf. *elongata.*

Occurence: — Oslo—Asker (5a, Bærum; 5b, Hovedøya), Ringerike (5a, Frognøy) — Esthonia (Porkuni Limestone, Porkuni), N. Germany (glacial drift boulders).

Platybolbina umbonata (KRAUSE, 1892)

(Pl. 4, figs. 1—3.)

1892 *Primitia* (*Ulrichia*?) *umbonata* n.sp. — KRAUSE, p. 389, pl. XXI, figs. 10—11.
1933 *Platychilina* (=*Primitia*) *umbonata* (KRAUSE) — KUMMEROW, p. 45.
1934 *Platychilina* (=*Primitia*) *umbonata* (KRAUSE) — KUMMEROW, p. 502,
1934 *Eurychilina* (*Coelochilina*) *umbonata* (KRAUSE) — BASSLER & KELLETT. p. 317.
1941 *Eurychilina* (*Platychilina*) *umbonata* (KRAUSE) — TRIEBEL, p. 314, pl. 4, fig. 42.

Type data: — As lectotype is here chosen one of the specimens figured by KRAUSE (1892), namely the left valve of which was later given a photograph by TRIEBEL (1941). It was described from an Ordovician drift boulder in N. Germany.

Present material: — Some 30 valves and impressions of valves, all preserved in limestone.

Remarks: — This rather small species (reaching a size of about 1.5 × 1.0 mm) is easily recognisable by its unusually large node and its very wide entire frill, rising up from the sagittal plane and thus giving a collar-like impression. The Norwegian material agrees quite well with the German drift specimens. KUMMEROW (1933, p. 45; 1934, p. 502) believed that the node takes the place of the muscle scar in *P. distans.* As shown by TRIEBEL (1941, p. 314, pl. 4, fig. 42) there is, however, a small pit behind the node, indicating that the muscle scar is situated behind the node, as usual. No dimorphism has been observed. Nevertheless, *P. umbonata* appears to be rather close to other species assigned to *Platybolbina*.

Occurrence: — Ringerike (5a, Frognøy, associated with *Bollia duplex* and *Platybolbina* cf. *plana*) — N. Germany (glacial drift boulder).

Genus *Laccochilina* HESSLAND, 1949

Type species: — By original designation, *Eurychilina estonula* ÖPIK, 1935b.

Laccochilina tarda sp.n.

(Pl. 6, figs. 8—9.)

Name: — The name *tarda* alludes to the late appearance of this species of *Laccochilina*.

Type data: — Holotype (P.M.O. — 66436) is a right valve (female type) from 5b at Hovedøya, Oslo.

Material: — About 15 valves and impressions of valves preserved in limestone.

Diagnosis: — A *Laccochilina* species with comparatively large node, well developed sulcal slit, well developed dorsal plica (ridge) and densely granulate surface. Anterior end narrower than posterior end.

Description: — Adult valves reach a length of about 2.4 mm and a height of about 1.4 mm. Ends subequal, but the anterior end is somewhat narrower than the posterior end. A short, slit-like, slightly curved sulcus is developed behind a comparatively large, round node. Dorsal plica well developed. It turns round at the ends to run subparallel with the free borders for a short distance; slightly further down ventrally at the anterior end than at the posterior end. Velate frill entire, rather narrow, faintly radially striate. It is slightly incurved in some specimens (female type). Surface (including frill) densely granulate.

Affinities: — This species resembles the Lower Ordovician species of *Laccochilina* described by HESSLAND (1949). It differs inter alia in having a much larger node.

Occurrence: — Oslo—Asker (5b, Hovedøya; 5a, Asker; 5a, Bærum) Ringerike (5a, Frognøy).

Genus *Öpikella* THORSLUND, 1940

Type species. — By original designation, *Öpikella tvaerensis* THORSLUND, 1940. As suggested by HENNINGSMOEN (1953, p. 228) this species may be based on valves of the male type, whereas *Ö. asklundi* THORSLUND, 1940 apparently represents valves of the female type of the same species, and should be considered a synonym of *Ö. tvaerensis*. The description of the following two species, both showing similar dimorphism, supports this assumption.

Öpikella frequens (STEUSLOFF, 1894)

(Pl. 5, figs. 7—9.)

1892 *Isochilina* (= ? *Leperditia brachynotus* FR. SCHMIDT) — KRAUSE, p. 398.

1894 *Isochilina frequens* n.sp. (*Leperditia brachynotus* FR. SCHMIDT ?) — STEUSLOFF, p. 784, pl. LVIII, fig. 4.

1924 *Aparchites* (?) *frequens* STEUSL. sp. — KUMMEROW, p. 415, pl. 20, (=21) fig. 4.

1934 *Isochilina frequens* STEUSLOFF — BASSLER & KELLETT, p. 339.

Type data: — Lectotype (here chosen) is the valve (female type) figured by STEUSLOFF (1894). It comes from a glacial drift boulder (Leptaena Limestone) in N. Germany.

Present material: — A great number of valves and impressions of valves, preserved in limestone.

Description of present material: — Adult valves up to about 2.4 mm long and 1.5 mm high. Rather convex. Posterior end lower and more pointed than anterior end. Greatest height slightly in front of median line. Cardinal angles rather obtuse. Hinge line comparatively short, about 1/2 the length of the valve, depressed, bordered on both sides (in complete carapace) by a dorsal plica (ridge), which conceals the true dorsal border in lateral view, giving a slightly convex dorsal outline. Non-sulcate, but a subcentral, elliptical muscle scar is sometimes faintly visible, especially in wetted specimens. Velate frill dimorphic. Male type: — velate frill flat and very narrow; dorsally (at both ends) replaced by a bend between the lateral and the narrow marginal surface. This velate bend appears to be confluent with the dorsal plica. Female type: — Velate frill slightly incurved, narrow, but markedly wider than in valves of the male type. The frill reaches from about the anterior extremity of the valve to just below the most posterior point. It ends rather abruptly at both ends. Dorsal to the frill (at both ends) it is replaced by a velate bend as in valves of male type. Surface of valve smooth.

Remarks: — The present material agrees very well with the two specimens figured by STEUSLOFF (1894) and KUMMEROW (1924) — both of the female type. For discussion of affinities, see next species.

Occurrence: — Oslo—Asker (5b, Hovedøya; 5b, Sandviksåsen), Ringerike (5a, Stavnestangen) — N. Germany (drift, Leptaena Limestone, Algal Limestone), Esthonia (Porkuni Limestone, Porkuni).

Öpikella cf. *umbilicata* (KUMMEROW, 1924)

(Pl. 5, figs. 1—6.)

cf. 1924 *Primitiella umbilicata* n.sp. — KUMMEROW, p. 420, pl. 20 (=21), fig. 14.

cf. 1934 *Primitiella umbilicata* KUMMEROW — BASSLER & KELLETT, p. 464.

Type data: — Lectotype (here selected) of *Öpikella umbilicata* is the left valve figured by KUMMEROW (1924). It comes from a glacial drift boulder of late Upper Ordovician age in N. Germany.

Present material: — Three carapaces and a great number of separate valves and moulds of valves, preserved in limestone.

Description of present material: — Adult valves up to about 1.8 mm long and 1.2 mm high. Moderately convex. Ends subequal. Cardinal angles obtuse. Hinge line about 3/4 the length of the valve, depressed, bordered on both sides (in a complete carapace) by a dorsal plica, which conceals the true dorsal border in lateral view, The dorsal plica is straight. Non-sulcate, but a subcentral, elliptical muscle scar may break the even convexity of the valve. Sometimes the edges of the scar are very faintly swollen (posteriorly sometimes forming a small post-sulcal node), and in some specimens the scar itself is slightly elevated above the general surface. In its dorsal end the scar may be extended into a faint stripe towards the dorsal border. Velate structure dimorphic. In valves of the male type it is developed as an extremely narrow frill (ridge) along the ventral border area. In valves of the female type the frill is comparatively wide, tapering evenly at both ends. The frill is smooth or somewhat irregularly striate. Anteriorly it reaches further up dorsally than in the valves of the male type. The female type of frill is slightly convex and deviates only slightly from the lateral surface of the valve. Marginal structure tuberculate. Surface of valve smooth, or finely granulose, especially in the border areas. A few larger granules may also be developed.

Remarks: — Valves of the male type agree with the lectotype in size and outline, in the presence of a dorsal plica, and in the type of muscle scar. The lectotype seems, however, to have a somewhat wider frill, and for this reason the present material may be referred to as *Ö.* cf. *umbilicata*.

Ö. cf. *umbilicata* resembles *Ö. frequens*, but the latter differs in having a shorter hinge line (about ½ length of valve as compared to about ¾ length of valve in *Ö.* cf. *umlilicata*), and in having a convex dorsal outline of the dorsal plica (straight in *Ö.* cf. *umbilicata*). Furthermore the velate frills in the female type of valves are rather different. Both forms appear to be closely related to the type species, *Ö. tvaerensis*, where, however, the valves of the male type have no velate frill, only a velate ridge. As suggested by THORSLUND (1940, p. 181) *Isochilina canaliculata* KRAUSE (1892, p. 385, pl. 21, fig. 1) is probably also congeneric. Only valves of the male type of this species have been described.

Occurrence: — Oslo—Asker (4dα—γ, Kråkeholmen, Asker; 5b, Hovedøya; 5b, Sandviksåsen; 5a, Bondibråten), Ringerike (5a, Stavnestangen) — N. Germany (drift, Upper Ordovician limestone).

?Subfamily Euprimitiinae HESSLAND, 1949

? Genus *Primitiella* ULRICH, 1894

Type species: — By original designation, *Primitiella constricta* ULRICH, 1894.

Primitiella? cf. *rara* (TROEDSSON, 1918)

(Pl. 1, fig. 12.)

1918 *Ctenobolbina rara* n.sp. — TROEDSSON, p. 54, pl. II, fig. 18.
1934 *Ctenobolbina rara* TROEDSSON — BASSLER & KELLETT, p. 254.

Type data: — Holotype (by monotypy) is the right valve figured by TROEDSSON (1918), from the Brachiopod Shale in Scania (Sweden).

Present material: — A few separate valves, preserved in limestone.

Remarks: — The present material agrees rather well with the holotype in outline, and in type and position of the presulcal node, sulcus, and postero-ventral node (spine). No faint depression is, however, developed in front of the postero-ventral node, as in the holotype. This depression may be accidental, as the holotype is preserved in shale, and is thus compressed (whereas the present material is preserved in limestone). *Primitiella? rara* is probably not related to *Ctenobolbina*, which has a distinct velate frill and a long median sulcus (cf. HENNINGSMOEN, 1953, p. 211). *Laccoprimitia? nodosa* HENNINGSMOEN, 1948 is closely related, but appears to have smaller nodes. Both species may tentatively be included in *Primitiella*, but they differ from this genus in having a well developed sulcus, and should perhaps later be removed from this genus.

Occurrence: — Oslo—Asker (5b, Hovedøya) — *P.? rara:* Brachiopod Shale, Scania (Sweden).

Family Aparchitidae JONES, 1901

?Genus *Macronotella* ULRICH, 1894

Type species: — By original designation, *Macronotella scofieldi* ULRICH, 1894.

Macronotella cf. *praelonga* (STEUSLOFF, 1894)

(Pl. 6, figs. 1—2.)

cf. 1894 *Leperditia praelonga* n.sp. — STEUSLOFF, p. 781, pl. LVIII, fig. 3.
?1894 *Leperditia Krausei* n.sp. — STEUSLOFF, p. 783, pl. LVIII, fig. 1.
?1894 *Leperditia* (?) *Kiesowii* n.sp. — STEUSLOFF, p. 784, pl. LVIII, fig. 2.
1901 *Leperditia* sp. — KIÆR, p. 79.
cf. 1924 *Leperditia praelonga* STEUSL. — KUMMEROW, p. 407.
?1924 *Leperditia Krausei* STEUSL. — KUMMEROW, p. 408.
?1924 *Leperditia Kiesowi* STEUSL. — KUMMEROW, p. 407.
cf. 1934 *Macronotella praelonga* (STEUSLOFF) — BASSLER & KELLETT, p. 407.
?1934 *Macronotella krausei* (STEUSLOFF) — BASSLER & KELLETT, p. 407.
?1934 *Macronotella kiesowii* (STEUSLOFF) — BASSLER & KELLETT, p. 407.

Type data: — Holotype (by monotypy) of *M. praelonga* is the valve figured by STEUSLOFF (1894) from a drift boulder (Borkholm = Porkuni Limestone) in N. Germany.

Material: — Two valves, preserved in limestone.

Description of present material: — The larger specimen is about 3.9 mm long and 2.8 mm high; the other specimen (crushed) is 2.2 mm high. Ends subequal, with obtuse cardinal angles. Moderately and evenly convex, except for the subcentral, elliptical muscle scar which is faintly depressed. In the larger specimen there is a probably more or less accidental pit in the muscle scar. Surface rather densely covered with granules, except in the muscle scar. The granules appear to have been hollow, as they are replaced by deep pits where the valve is worn, especially in the dorsal half of the crushed specimen.

Remarks: — According to KUMMEROW (1924) the holotypes of *Macronotella kiesowii* and *M. krausei* are badly preserved, and the hinge line in STEUSLOFF's figure of *M. praelonga* is quite illusory. The outlines of all three species, as figured by STEUSLOFF, appear rather questionable. Possibly the specimens are either damaged or not quite cleaned of matrix. According to STEUSLOFF, *M. praelonga* is covered by fine granules, whereas *M. krausei* and *M. kiesowii* have deep pits instead. This may possibly be due to whether or not the valves were worn (cf. above). All three agree in their unusual large size, and in coming from drift boulders of late Upper Ordovician age; *M. praelonga* was described from a drift boulder of Borkholm (=Porkuni) Limestone associated with «*Primitia*» *jonesii* (=*jonesiana*), «*P.*» *distans*, «*P.*» *plana*, «*P.*» *cuneata*, «*P.*» *rugosa*, «*P.*» *canaliculata*, and «*P.*» *elongata obliqua*, whereas *M. krausei* and *M. kiesowii* occurred together in a drift boulder of Leptaena Limestone associated with «*Isochilina*» *frequens* and «*Primitia*» *elongata semicircularis*. To the writer, it seems possible that *M. praelonga*, *M. krausei*, and *M. kiesowii* are conspecific. It should, however, be checked, if possible, in the type material.

The Norwegian material agrees with these three species in the large size, types of surface ornamentation, and in coming from beds of the same age.

Occurrence: — Oslo—Asker (5a, Holtebråten in Asker), Ringerike (5a, Stavnestangen) — N. Germany (glacial drift boulders).

Associated with: — (the larger specimen): *Öpikium porkuniensis* sp.n., (the crushed specimen): *Kiesowia dissecta*, *Öpikium porkuniensis* sp.n., *Platybolbina* cf. *plana*, *Öpikella frequens*, *Bollia duplex*, *Primitia norvegica* sp.n., *Bolbina tuberculata* sp.n., *Macronotella* sp.

Macronotella spp.

Remarks: — Valves of *Macronotella* species are commonly met with. They vary in size, convexity, and outline. Some may possibly be larval moults of *M.* cf. *praelonga*. «*Leperditia brachynota*» listed by KIÆR (1901, p. 79) from 5b at Nyborg in Asker appears to be a *Macronotella* species.

Occurrence: — Oslo—Asker (5a, Nedre Ås in Bærum; 5a, Bondibråten; 5b, Sandviksåsen; 5b, Nyborg in Asker), Ringerike (5a, Stavnestangen).

Family Drepanellidae ULRICH & BASSLER, 1923

?Subfamily Bolliinae BOUČEK, 1936

Genus *Bollia* JONES & HOLL, 1886

Type species: — *Bollia uniflexa* JONES & HOLL, 1886 (designated by MILLER, 1892, p. 706).

Bollia duplex KRAUSE, 1892.

(Pl. 2, figs. 6—7.)

1892 *Bollia duplex* n.sp. — KRAUSE, p. 392, pl. XXI, fig. 7.
1934 *Bollia duplex* KRAUSE — BASSLER & KELLETT, p. 217.

Type data: — Lectotype (here selected) is the left valve figured by KRAUSE (1892) and described by him from a glacial drift boulder in N. Germany. It is associated with *Platybolbina distans* and *P. umbonata*, and may safely be regarded as of late Upper Ordovician age.

Present material: — 12 partly damaged valves and internal moulds of valves, all preserved in limestone.

Description of present material: — Rather large; adult valves up to about 2.3 mm long and 1.5 mm high. Ends subequal; both cardinal angles markedly obtuse. Its pattern is characterized by two rather wide and concentric ridges. The inner loop is probably formed by L2 and parts of L3. Its anterior branch (L2) is rather straight (but somewhat swollen dorsally), whereas its posterior branch has a characteristic, angular course. Beneath this branch there is a nodelike swelling, which, together with the ridge, probably represents L3. The swelling is best seen in the corner formed by the posterior branch of the inner loop. A well defined sulcus is developed between L2 and L3. The outer, submarginal ridge of the valve is partly formed by L1 and L4, and thus represents a carinal ridge (or, possibly, a fused carinal and velate ridge). A thin, marginal ridge runs along the free borders. The surface of the valve appears smooth.

There is some variation in the development of the ridges. Especially in larval valves they tend to be more swollen. This is similar to the conditions in the rather *Bollia*-like *Tallinnella mjoesensis* HENNINGSMOEN (1953b, p. 39).

Occurrence: — Oslo—Asker (5b, Hovedøya), Ringerike (5a, Frognøy, 5a, Stavnestangen).

Bollia accentuata sp.n.

(Pl. 2, figs. 8—9.)

Name: — The name *accentuata* alludes to the accentuated relief of this species.

Type data: — Holotype (P.M.O. — 66423) is a left valve from 5b at Hovedøya, Oslo.

Material: — A few separate valves, preserved in limestone.

Diagnosis: — A *Bollia* species with high U-shaped ridges. The inner ridge which is separated from the outer ridge by a narrow groove has both dorsal ends swollen into large nodes. There is also a faint swelling in the postero-ventral part of this ridge. The outer ridge is close to the margin.

Description: — Valves about 1.2 × 1.0 mm. Subequal ends. The outer U-shaped ridge is subparallel to the free borders, but does not quite reach the dorsal margin posteriorly. The inner U-shaped ridge is separated from the outer ridge by a narrow groove. Both its dorsal ends are swollen into large nodes, the anterior node being somewhat larger than the posterior node. A faint swelling of the ridge is developed postero-ventrally. The relief is high. Surface seems smooth.

Remarks: — The present species may be compared with *Bollia biplicata* (TROEDSSON, 1918) from the Brachiopod Shale in Scania (Sweden), but the latter form has not such a well-defined outer ridge, and the inner ridge is more even.

Occurrence: — Oslo—Asker (5b, Hovedøya).

Genus *Pseudulrichia* SCHMIDT, 1941

Type species: — By original designation, *Leperditia bivertex* ULRICH, 1879.

Pseudulrichia norvegica sp.n.

(Pl. 6, figs. 6—7.)

Type data: — Holotype (R.M. — Ar. 36426) is a right valve from 5b at Hovedøya, Oslo.

Material: — Some 25, usually more or less damaged valves, preserved in limestone.

Diagnosis: — A *Pseudulrichia* species with two rather large horns; anterior horn with blunt end, posterior horn drawn out into a spine.

Description: — Adult valves about 1.8 mm long and 1.2 mm high, excluding horns. Ends subequal, both cardinal angles obtuse. Surface evenly convex, except for the two rather dominating horn-like processes in the dorsal half, and a sulcus between them. The anterior horn (L2) has a round base, is somewhat bulbous and ends bluntly. It is about as high as it is wide at its base. The posterior horn (L3) has a round base of the same size as the anterior horn, but is drawn out into a spine, about twice as high (long) as the anterior horn. No submarginal structures are present. No dimorphism was observed. The surface is smooth.

Remarks: — *P. norvegica* resembles the type species, which, however, has two nodes instead of two horns. Some Bohemian species assigned to *Parulrichia* SCHMIDT, 1941 by SCHMIDT (1941) have such horns, and may be congeneric. The type species of *Parulrichia*, *Primitia diversa* JONES & HOLL, 1886, appears to belong to another family.

Occurrence: — Oslo—Asker (5b, Hovedøya).

Family Acronotellidae SWARTZ, 1936

?Genus *Monoceratella* TEICHERT, 1937a

Type species: — By original designation, *Monoceratella teres* TEICHERT, 1937a.

Known Stratigraphical and Geographical Distribution of the Upper Ordovician Paleocop Ostracods found in the Oslo Region	Oslo Region, Norway						Scando-Baltic Drift Boulders in N. Germany			Esthonia
	Oslo—Asker				Ringerike					
	Tretaspis Series		Dalmanitina Series		Dalmanitina Series		Leptaena Lst.	Unspecified	Porkuni Lst.	Porkuni Lst.
	4c	4d	5a	5b	5a	5b				
1. *Sigmobolbina?* sp.				1						
2. *Bolbina* aff. *minor* (KRAUSE)				2						
3. *Bolbina tuberculata* sp.n.				3						
4. *Kiesowia dissecta* (KRAUSE)			4?	4	4					4
5. *Tetradella plicatula* (KRAUSE)			5?	5						5
6. *Öpikium porkuniensis* sp.n.				6	6					6
7. *Primitia osloensis* sp.n.				7	7					
8. *Chilobolbina?* cf. *jonesiana* (SCHMIDT)			8?	8					8	
9. *Platybolbina* cf. *plana* (KRAUSE)			9	9	9		9		9	
10. *Platybolbina tiara* sp.n.				10						
11. *Platybolbina* cf. *elongata* (KRAUSE)			11	11	11			11		11
12. *Platybolbina umbonata* (KRAUSE)					12			12		
13. *Laccochilina tarda* sp.n.			13	13						
14. *Öpikella frequens* (STEUSLOFF)				14	14		14			14
15. *Öpikella* cf. *umbilicata* (KUMMEROW)		15	15	15	15			15		
16. *Primitiella* cf. *rara* (TROEDSSON)				16						
17. *Macronotella* cf. *praelonga* (STEUSLOFF)			17		17		17?		17	
18. *Macronotella* spp.			18	18	18					
19. *Bollia duplex* (KRAUSE)				19	19			19		
20. *Bollia accentuata* sp.n.				20						
21. *Pseudulrichia norvegica* sp.n.				21						
22. *Monoceratella bos* sp.n.				22						

NB. The «cf.»s apply only to the material from the Oslo Region.

Monoceratella bos sp.n.

(Pl. 6, figs. 3—4.)

Name: — The name *bos* (bull) alludes to the bull-like horns of this species.

Material: — Two valves, preserved in limestone.

Diagnosis: — A small *Monoceratella* species with long, slightly dorsal spines.

Description: — The two valves present are 1.2 × 0.7 and 0.8 × 0.5 mm. Valve elongate, slightly triangular in outline. A long, slender spine is developed in each of the dorsal corners. The spines are oblique, and slightly curved. The postero-ventral spine is broken off in both specimens. Surface smooth. Since both valves are right valves, the overlap features are not known.

Remarks: — Three species of *Monoceratella* have been described from the Middle Ordovician of Arctic Canada and N. Greenland by TEICHERT (1937a, 1937b). TEICHERT (1937b, p. 54) included in this genus also *Isochilina armata* var. *pygmaea* RUEDEMANN, 1901 from the Rysedorph conglomerate of New York. None of these species have dorsal spines as long as *M. bos*.

The taxonomic position of *Monoceratella* is rather uncertain (cf. HENNINGSMOEN, 1953, p. 234).

Occurrence: — Oslo—Asker (5b, Hovedøya).

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PLATES 1–6

All specimens were whitened before photographing. Photographer: Miss B. Mauritz.

P.M.O. = Paleontological Museum of the University in Oslo.

R.M. = Paleozoological Department of the State Museum of Natural History, Stockholm.

PLATE 1.

The background has been blackened in figs. 3—5, 7, and 10, and the sulcus slightly retouched in fig. 7. Otherwise no retouching.

Sigmobolbina? sp. 77

Fig. 1. Left valve. P.M.O. — 66437. 5b, Hovedøya, Oslo. Coll.: G. Henningsmoen, 1953. × 20.

Fig. 2. Left valve. P.M.O. — 66438. 5b, Hovedøya, Oslo. Coll.: G. Henningsmoen, 1953. x 20.

Bolbina tuberculata sp.n. ....p. 78

Fig. 3. Left valve. P.M.O. — 66428 b. 5b, Hovedøya, Oslo. Coll.: G. Henningsmoen, 1953. x 20.

Fig. 4. Left valve. R.M. — Ar 36454. 5b, Hovedøya, Oslo. Coll.: G. Holm, 1877. x 20.

Fig. 5. Left valve. Holotype. P.M.O. — 66428 a. 5b, Hovedøya, Oslo. Coll.: G. Henningsmoen, 1953. x 20.

Primitia osloensis sp.n. ....p. 83

Fig. 6. Left valve, female type. Holotype. P.M.O. — 55081 a. 5a, Stavnestangen, Ringerike. Coll.: J. Kiær, 1919. x 20.

Fig. 7. Left valve, female type. R.M. — Ar. 36452 b. 5b, Hovedøya, Oslo. Coll.: G. Holm, 1877. x 22.

Tetradella plicatula (KRAUSE) ....p. 80

Fig. 8. Badly preserved left valve. P.M.O. — 12511 a. 5a (-b), Nedre Ås, Bærum. Coll.: J. Kiær, 1905. x 20.

Fig. 9. Impression of left valve. P.M.O. — 12511 b. Counterpiece of specimen in fig. 8. x 16.

Fig. 10 .Badly preserved right valve, showing, however, some of the subventral loculi. P.M.O. — 12511d. 5a(-b), Nedre Ås, Bærum. Coll.: J. Kiær, 1905. x 20.

Fig. 11. Anterior part of left valve. R.M. — Ar. 36463. 5b, Hovedøya, Oslo, Oslo. Coll.: G. Holm, 1877. x 20.

Primitiella? cf. *rara* (TROEDSSON)..........................p. 95

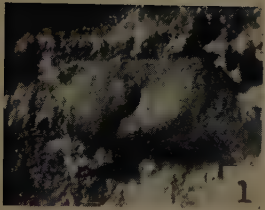
Fig. 12. Right valve. P.M.O. — 66430. 5b, Hovedøya, Oslo. Coll.: G. Henningsmoen, 1953. x 17.

Bolbina aff. *minor* (KRAUSE) ....p. 77

Fig. 13. Right valve. P.M.O. — 12510b. 5a(-b), Nedre Ås, Bærum. Coll.: J. Kiær, 1905. x 20.

Platybolbina cf. *elongata* (KRAUSE) ....p. 90

Fig. 14. Left valve, clearly showing the muscle scar. Male type. P.M.O. — 14469d. 5a, Frognøy, Ringerike. Coll.: J. Kiær, 1909. x 22.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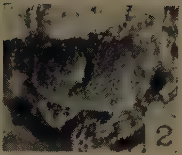
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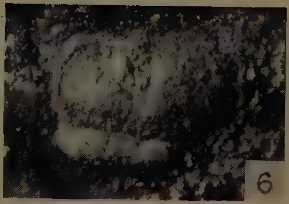
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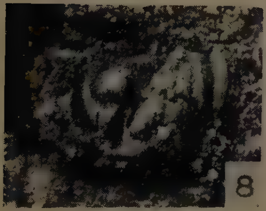
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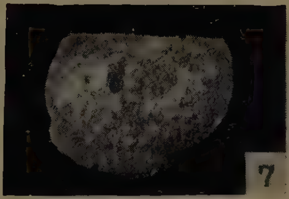
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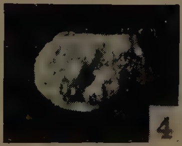
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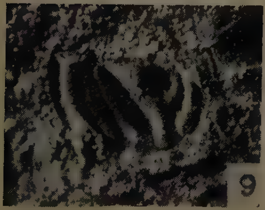
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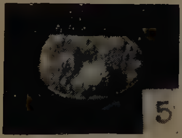
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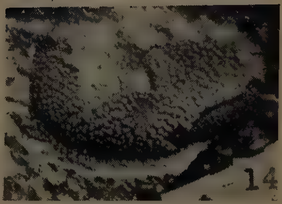
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PLATE 2.

The background has been blackened in figs. 5 and 8. Otherwise no retouching.

Kiesowia dissecta (KRAUSE) ....p. 78

Fig. 1. Internal mould of left valve, with parts of test preserved dorsally. P.M.O. — 18722. 5a, Stavnestangen, Ringerike. Coll. J. Kiær, 1914. x 23.

Fig. 2. Right valve. Test partly missing, but frill present. P.M.O. — 15721. 5a, Stavnestangen, Ringerike. J. Kiær, 1915. x 22.

Fig. 3. Left valve, showing frill (somewhat broken). R.M. — Ar. 36424. 5b, Hovedøya, Oslo. Coll.: G. Holm, 1877. x 22.

Fig. 5. Right valve, larval form showing three nodes in L1 and the pitted surface. P.M.O. — 66439. 5b, Hovedøya, Oslo. Coll.: G. Henningsmoen, 1953. x 20.

Öpikium porkuniensis sp. n. ....p. 82

Fig. 4. Right valve, female type. R.M. — Ar. 36425. 5b, Hovedøya, Oslo. Coll.: G. Holm, 1877. x 10.

Bollia duplex KRAUSE ....p. 98

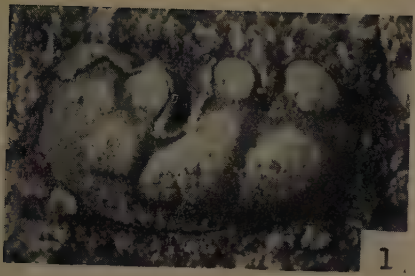
Fig. 6. Left valve (anterior and ventral border concealed by matrix). R.M. — Ar. 36426 d. 5b, Hovedøya, Oslo. Coll.: G. Holm, 1877. x 21.

Fig. 7. Left valve with less pronounced relief. R.M. — Ar. 36426 a. 5b, Hovedøya, Oslo, Coll.: G. Holm 1877. x 23.

Bollia accentuata sp.n. ....p. 99

Fig. 8. Right valve. P.M.O. — 66431. 5b, Hovedøya, Oslo. Coll.: G. Henningsmoen, 1953. x 20.

Fig. 9. Left valve. Holotype. P.M.O. — 66432. 5b, Hovedøya, Oslo. Coll.: G. Henningsmoen, 1953. x 20.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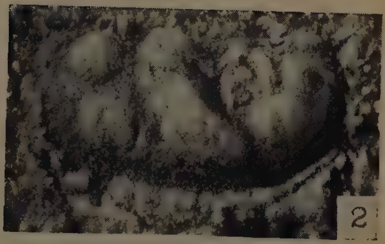
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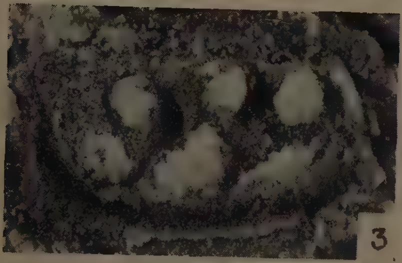
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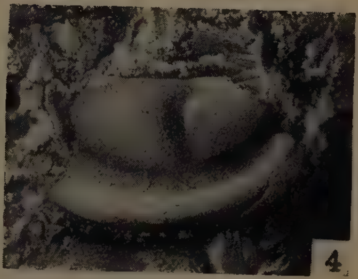
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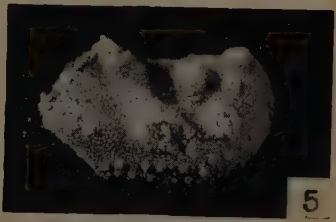
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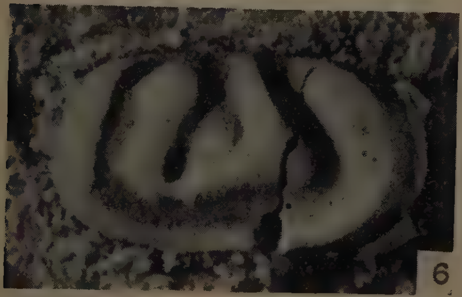
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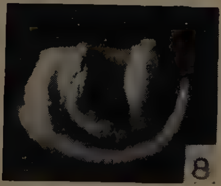
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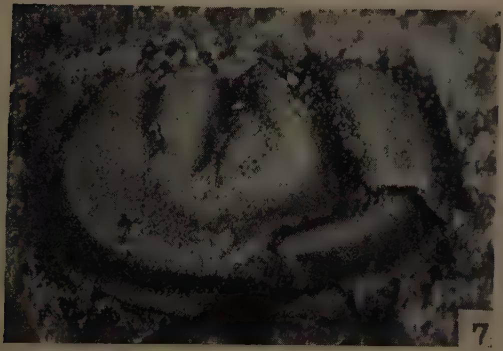
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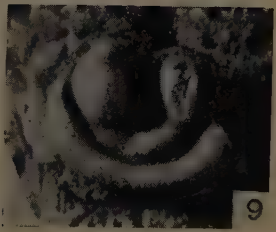
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PLATE 3.

No retouching.

Platybolbina cf. *plana* (KRAUSE) ....p. 87

Fig. 1. Left valve with pitted surface and well developed muscle mark. Female type. P.M.O. — 66435. 5b, Hovedøya, Oslo. Coll.: G. Henningsmoen, 1953. x 20.

Fig. 2. Left valve with typical outline; partly exfoliated. Female type. R.M. — Ar. 36472 a. 5b, Hovedøya, Oslo. Coll.: G. Holm, 1877. x 20.

Fig. 3. Right valve, rather high. Male type. R.M. — Ar. 36458. 5b, Hovedøya, Oslo. Coll.: G. Holm, 1877. x 22.

Fig. 4. Left valve with rather wide frill. Female type. P.M.O. — 18164 c. 5a, Stavnestangen, Ringerike. Coll.: J. Kiær, 1911. x 21.

Fig. 5. Left valve with typical outline; partly exfoliated. Male type. P.M.O. — 20582. 5a, Sandviksåsen, Bærum. Coll.: J. Kiær, 1894. x 22.

Fig. 6. Left valve, female type. R.M. — Ar. 36461 a. 5b, Hovedøya, Oslo. Coll.: G. Holm, 1877. x 23.

Fig. 7. Left valve, female type. P.M.O. — 55084. 5a, Stavnestangen, Ringerike. Coll.: J. Kiær, 1919. x 22.

Fig. 8. Right valve, female type. R.M. — Ar. 36426 c. 5b, Hovedøya, Oslo. Coll.: G. Holm, 1877. x 22.

PLATE 3

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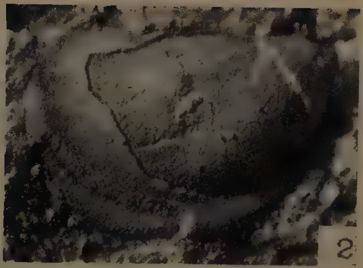
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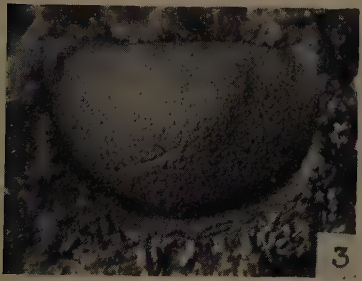
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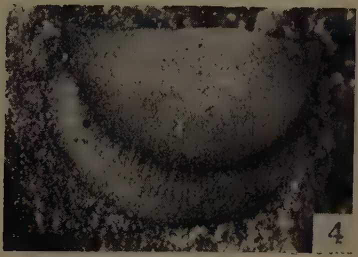
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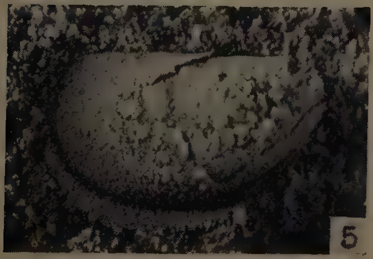
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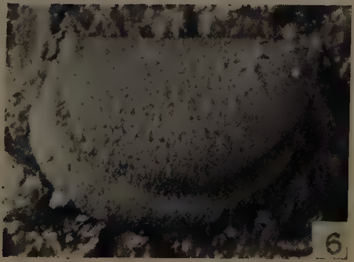
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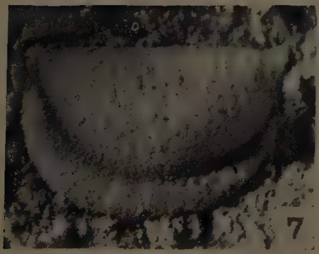
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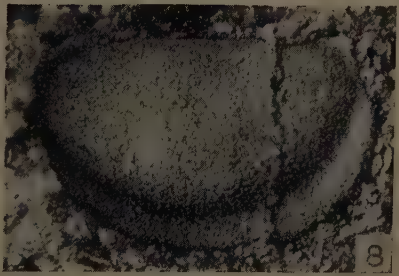
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PLATE 4.

No retouching.

Platybolbina umbonata (KRAUSE) ....p. 91

Fig. 1. Right valve showing sulcal pit. P.M.O. — 14469 c. 5a, Frognøy, Ringerike. Coll.: J. Kiær, 1909. x 22.

Fig. 2. Right valve. P.M.O. — 14469 a. 5a, Frognøy, Ringerike. Coll: J. Kiær, 1909. x 22.

Fig. 3. Left valve, with presulcal node broken off. P.M.O. — 14469 b. 5a, Frognøy, Ringerike. Coll.: J. Kiær, 1909. x 22.

Platybolbina tiara sp. n. ....p. 89

Fig. 4. Left valve, female type. R.M. — Ar. 36472. 5b, Hovedøya, Oslo. Coll.: G. Holm, 1877. x 24.

Fig. 5. Left valve, male type. Part of frill broken off posteroventrally. R.M. — Ar. 36464 b. 5b, Hovedøya, Oslo. Coll.: G. Holm, 1877. x 20.

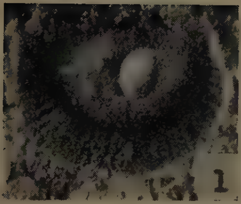
Fig. 6. Right valve, male type. Part of frill broken off posteroventrally. P.M.O. — 66428 c. 5b, Hovedøya, Oslo. Coll.: G. Henningsmoen, 1953. x 20.

Fig. 7. Left valve, female type. R.M. — Ar. 36452 c. 5b, Hovedøya, Oslo. Coll.: G. Holm. 1877 .x 20.

Fig. 8. Left valve, female type. Holotype. P.M.O. — 66434. 5b, Hovedøya, Oslo. Goll.: G. Henningsmoen, 1953. x 20.

Fig. 9. Right valve, female type. R.M. — Ar. 36461 b. 5b, Hovedøya, Oslo. Coll.: G. Holm, 1877. x 20.

PLATE 4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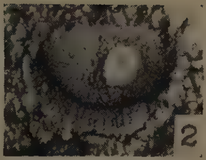
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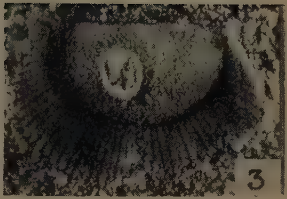
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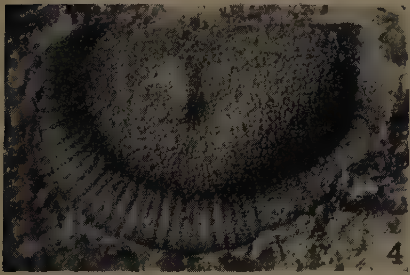
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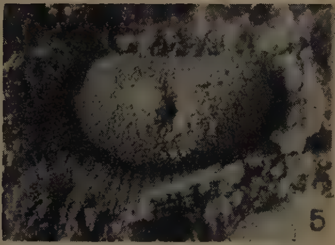
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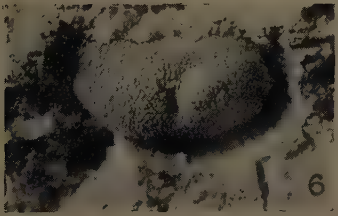
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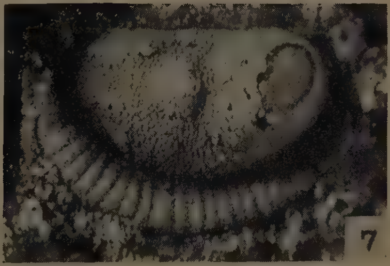
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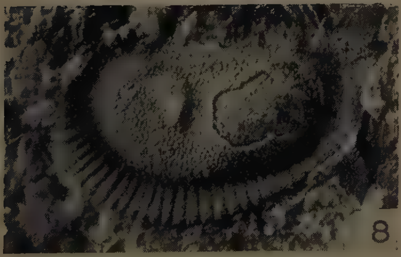
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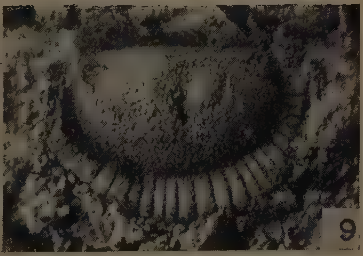
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PLATE 5.

No retouching.

Öpikella cf. *umbilicata* (KUMMEROW) ....p. 94

Fig. 1. Right valve, female type. P.M.O. — 18164 a. 5a, Stavnestangen, Ringerike. Coll.: J. Kiær, 1911. x 22.

Fig. 2. Right valve, male type. P.M.O. — 18164 b. 5a, Stavnestangen, Ringerike. Coll.: J. Kiær, 1911. x 22.

Figs. 3—5. Dorsal view (anterior end down), ventral view (anterior end down), and right side view of entire carapace. Male type. P.M.O. — 66420. 5b, Hovedøya, Oslo. Coll.: G. Henningsmoen, 1953. x 20.

Fig. 6. Right valve with pitted surface. Female type. P.M.O. — 12303. 5a, N of Bondivatnet, Asker. Coll.: J. Kiær, 1897. x 20.

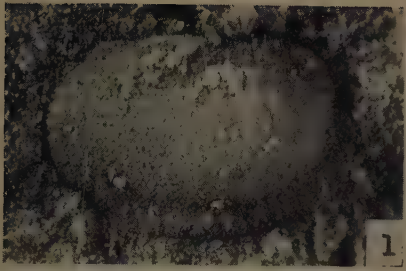
Öpikella frequens (STEUSLOFF) ....p. 93

Fig. 7. Right valve, male type. R.M. — Ar. 36464 a. 5b, Hovedøya, Oslo. Coll.: G. Holm, 1877. x 20.

Fig. 8. Right valve, female type. P.M.O. — 55081 b. 5a, Stavnestangen, Ringerike. Coll.: J. Kiær, 1919. x 23.

Fig. 9. Left valve, female type. R.M. — Ar. 36451. 5b, Hovedøya, Oslo. Coll.: G. Henningsmoen, 1953. x 20.

PLATE 5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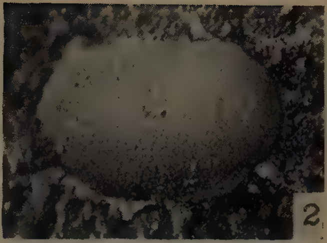
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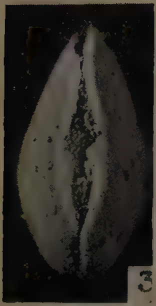
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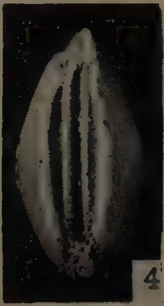
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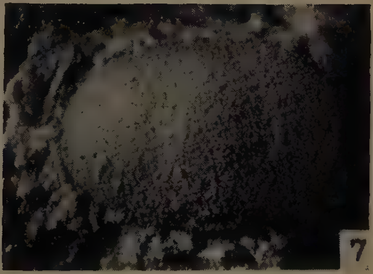
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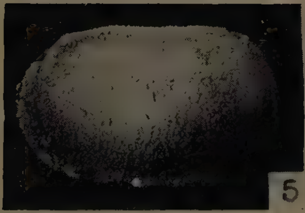
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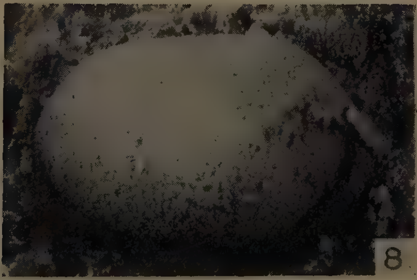
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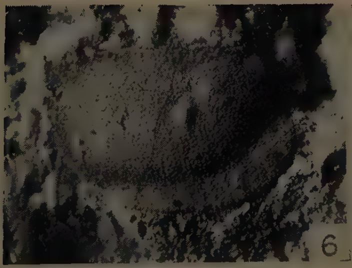
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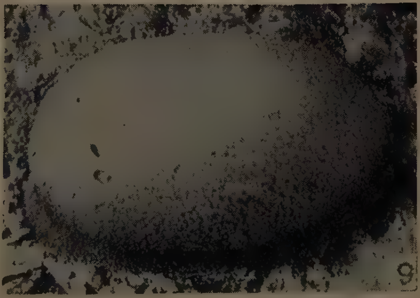
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PLATE 6.

No retouching.

Macronotella cf. *praelonga* (Steusloff) ....p. 96

Fig. 1. Left valve, partly crushed, but showing pits (= broken tubercles) on the surface. P.M.O. — 55081 c. 5a, Stavnestangen, Ringerike. Coll.: J. Kiær, 1919. x 14.

Fig. 2. Right valve. The pit in the muscle scar is probably accidental. P.M.O. — 11099. 5a, S of Holtebråten, Asker. Coll.: J. Kiær, 1897. x 10.

Monoceratella bos sp.n. ....p. 102

Fig. 3. Right valve. Holotype. P.M.O. — 12511 c. 5a (-b), Nedre Ås, Bærum. Coll.: J. Kiær, 1905. x 20.

Fig. 4. Right valve. P.M.O. — 12510a. 5a (-b), Nedre Ås, Bærum. Coll.: J. Kiær, 1905. x 20.

Chilobolbina? cf. *jonesiana* (Schmidt).......................p. 84

Fig. 5. Left valve. R.M. — Ar. 36452 a. 5b, Hovedøya, Oslo. Coll.: G. Holm, 1877. x 24.

Pseudulrichia norvegica sp. n. ....p. 100

Fig. 6. Dorsal view of right valve, partly imbedded in matrix, showing bluntly pointed anterior horn and sharply pointed posterior horn. P.M.O. — 66433. 5b, Hovedøya, Oslo. Coll.: G. Henningsmoen, 1953. x 20.

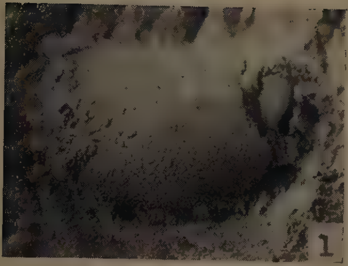
Fig. 7. Right valve, with broken horns. Holotype. R.M. — Ar. 36426 b. 5b, Hovedøya, Oslo. Coll.: G. Holm. 1877. x 22.

Laccochilina tarda sp. n. ....p. 92

Fig. 8. Left valve, male type. R.M. — Ar. 36462. 5b, Hovedøya, Oslo. Coll.: G. Holm, 1877. x 20.

Fig. 9. Right valve, female type. Holotype. P.M.O. — 66436. 5b, Hovedøya, Oslo. Coll.: G. Henningsmoen, 1953. x 20.

Plate 6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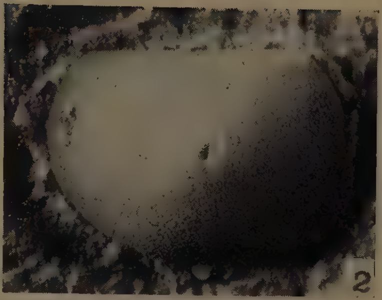
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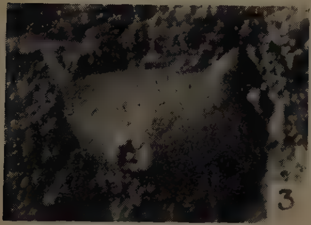
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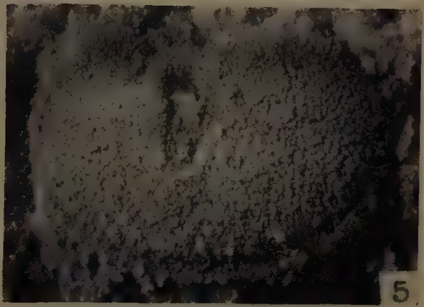
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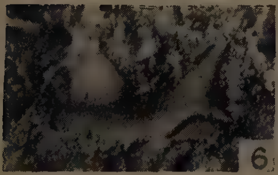
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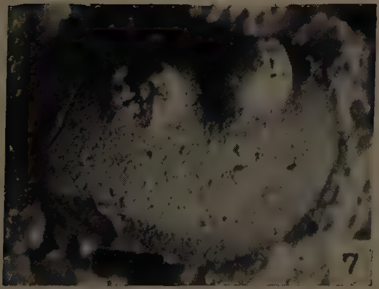
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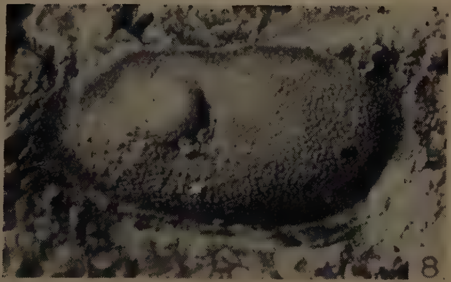
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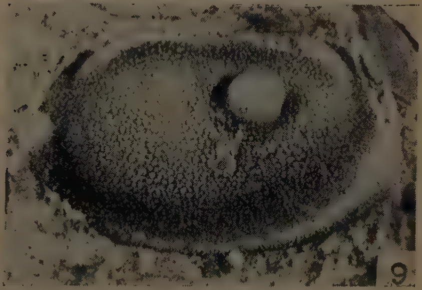
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NORSK GEOLOGISK TIDSSKRIFT 33

LATE-PLEISTOCENE FORAMINIFERA FROM THE OSLOFJORD AREA, SOUTHEAST NORWAY

BY

ROLF W. FEYLING-HANSSEN
(University of Oslo)

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Abstract: The present paper is a preliminary report on a quantitative study of the foraminiferal contents of Late- and Post-Glacial clay samples from the Oslofjord area. It appears that sediments of Late-Glacial and Post-Glacial age are sharply defined by a few dominent species in their foraminiferal faunas. A subdivision can be based partly on the dominance of some species and partly on the presence of certain accessory species. In this way, most samples from the area could be rapidly placed in the old stratigraphic scheme based on megafossils.

Introduction.

For the Oslofjord area BRØGGER (1900—1901) established a stratigraphy of the sediments deposited at the retreating front of the ice of the latest glaciation on the basis of their content of fossil pelecypods. He thus divided the clay sediments into the following main horizons: *Yoldia*-clay, *Arca*-clay, *Mytilus*- and *Cyprina*-clay, (of Late-Glacialage) *Cardium*-clay, *Ostrea*-clay, *Isocardia*-clay, (of Post-Glacial age), and *Mya*-clay which is of recent origin.

The *Yoldia*-clay is a high-arctic sediment. Its index fossil is *Portlandia arctica* (GRAY) (= *Yoldia arctica* GRAY) which at present lives only in arctic waters, *e.g.* Greenland and Spitsbergen. Norway was probably almost entirely covered by ice when the *Yoldia*-clay was deposited. In Southeast Norway this clay has only been found outside, *i. e.* to the south of, the large marginal moraine which is called the Ra (fig. 1).

During the retreat of the ice from the Ra the *Arca*-clay was deposited. Its index fossil is *Bathyarca glacialis* (GRAY) (= *Arca glacialis* GRAY). This clay was deposited under subarctic and high-boreal climatic conditions. It is found in the outer fjord regions northwards around Oslo. Towards the end of this period the shoreline at Oslo was situated at 221 m above the present sea-level, and the ice front receded from the Oslo area to the southern ends of the larger lakes in Southeast Norway.

During improving climatic conditions the *Mytilus*- and *Cyprina*-clay and the *Cardium*-clay (index fossil *Cardium edule* LINNEAUS) were deposited. The ice sheet disappeared and the climate approached the present one.

We then pass into the Post-Glacial warm period with the deposition of the *Ostrea*-clay (*Ostrea edulis* LINNAEUS). Somewhat later, at optimal climatic conditions, the *Isocardia*-clay was deposited. Its index fossil is *Isocardia cor* (LINNAEUS) and its mollusk fauna is very rich both in species and specimens. This unit coincides with the Atlanticum and the first part of the Subboreal.

At the end of the Post-Glacial warm period the climate once again grew less favourable and passed into the present one with the immigration of *Mya arenaria* LINNEAUS to Scandinavia. Between the *Isocardia*-clay and the *Mya*-clay BRØGGER placed a *Scrobicularia*-clay (*Scrobicularia plana* (DA COSTA)). This, however, should at many localities be regarded as a facial unit more than a stratigraphic one.

It is assumed that these sediments, from the *Yoldia*-clay to the

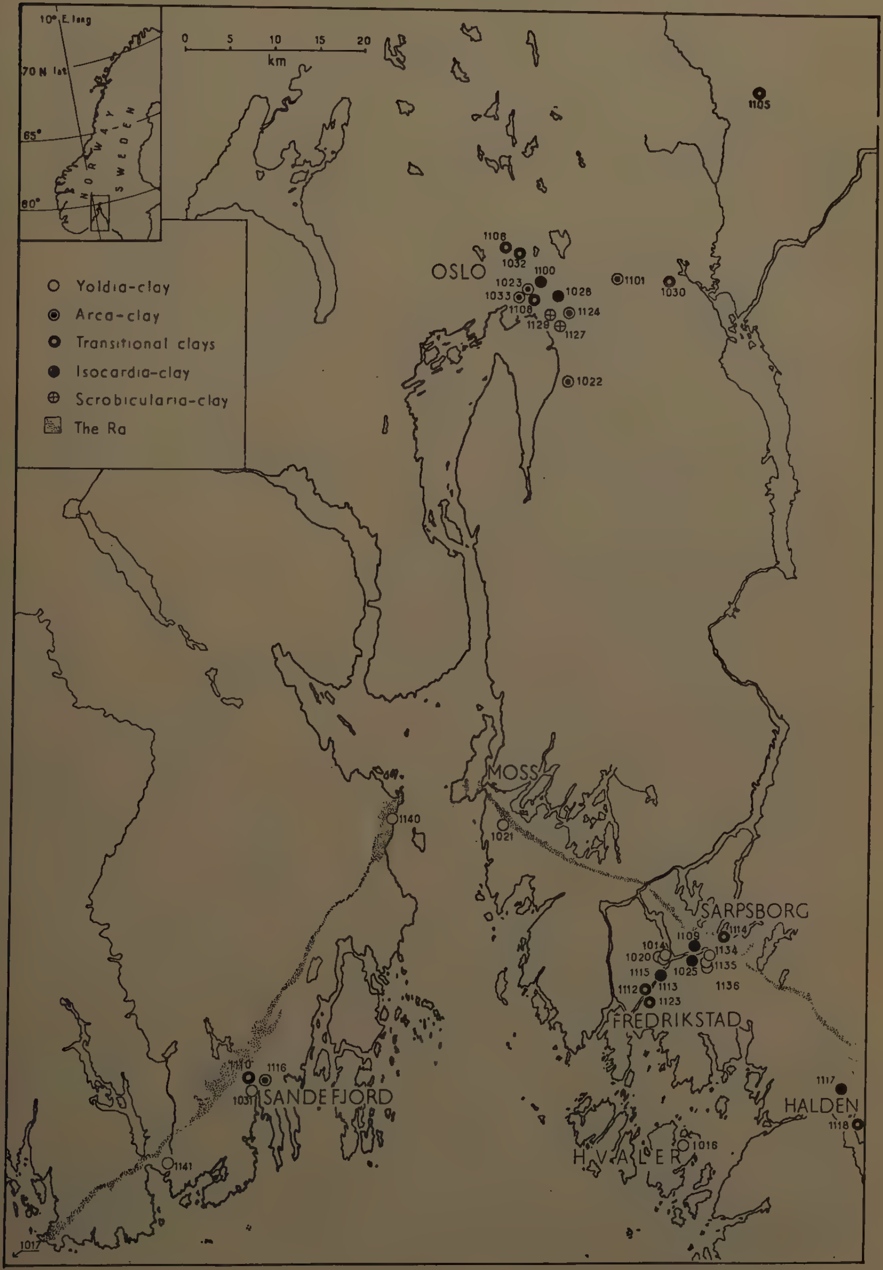

Fig. 1. The Oslofjord area with locations of samples.

Scrobicularia-clay have been deposited during a continous recovery of the land as the weight of the ice mass lessened. Consequently, the younger sediments are found at the lower altitudes. By the lowering of the shoreline, previously well ventilated waters often became more or less land-locked. This changing in the ecological conditions influenced the foraminiferal faunas in a way which has little to do with changing climates. Thus samples from the *Scrobicularia*-clay at Oslo contained only a few arenaceous forms.

In the literature only some scattered lists of species of Foraminifera from the marine Pleistocene of the Oslofjord area are found (M. SARS, 1865; CROSSKEY and ROBERTSON, 1868; KIÆR, 1900, and in BRØGGER, 1900—1901). Many of these older investigations, however, were made from a zoological point of view, rather than from a stratigraphical one. Generally only a few specimens of each species were considered, and the samples were evidently not always clean. The listed faunas therefore often received a mixed composition.

The present research, which is still in progress, does not aim at counting as many and as rare species as possible in each sample, but rather at finding out which species are the most common in each sediment, thus attempting a characterization of the different sediments by their dominant species. By this, it is hoped to introduce the Foraminifera as a practical aid when a rapid stratigraphic determination of samples from the marine Late-Pleistocene of the Oslofjord area is required. In order to reduce faunal variations caused by local environmental conditions ventilated sediments for the most part have been considered. Samples whose stratigraphic position are confirmed by their content of megafossils were preferred.

The samples have been brought together partly from the collections of the Paleontological Museum in Oslo, by courtesy of Professor Dr. A. HEINTZ and Curator H. ROSENDAHL, and partly from the field. All samples have been sieved through a 0,10 mm sieve. The photographs for the plates have been prepared by Miss BERGLIOT MAURITZ, the drawings for map and diagrams by Miss RANDI GULLIKSEN. Mechanical analyses were done by Mr. J. WILHELMSEN at Veglaboratoriet, Oslo. — The author thanks Norges Almenvitenskapelige Forskningsråd for financial support in the preparation of this article.

The Yoldia-clay.

The high-arctic *Yoldia*-clay is often somewhat coarse due to granules and even pebbles having been brought into the clay by floating ice. Mechanical analyses revealed median diameters varying from 0,0112 to 0,0042 mm, the samples being normally to poorly sorted (coefficient of sorting, So, varying from 3,16 to 5,64; cf. fig. 2).

12 samples of *Yoldia*-clay have been examined:

Sample nr. 1014 from Valle by Sarpsborg.
— - 1016 - Korshavn, Kirkeøya, Hvaler.
— - 1017 - Jomfruland, at Kragerø.
— - 1020 - Valle by Sarpsborg (another level).
— - 1021 - Dilling station by Moss.
— - 1031 - Pulsstad, Sandefjord.
— - 1115 - Valle by Sarpsborg (another level).
— - 1134 - Gretnes, Sarpsborg, 6 m below surface.
— - 1135 - Gretnes, Sarpsborg, 9 m below surface.
— - 1136 - Gretnes, Sarpsborg, 11 m below surface.
— - 1140 - Brårudåsen, Horten.
— - 1141 - Bøkeskogen, Larvik; 45 m above sea-lev.

All of them contained megafossils, amongst them being *Portlandia arctica*. Sample nr. 1140 contained no Foraminifera, and nr. 1141 yielded only two specimens of *Elphidium incertum clavatum* CUSHMAN. Two samples, nr. 1021 and nr. 1136, appeared to be contaminated and thus valueless. Eight samples were rather rich in specimens; between 300 and 1200 being picked out in each one. The number of species was poor: one sample contained 4 species, another contained 5, two samples contained 7 species, one contained 11, and three contained 12 species.

All samples showed a pronounced dominance of *Elphidium incertum clavatum* CUSHMAN this species accounting for 48—90 per cent of the faunas. Second in order, in all but two of the samples came *Cassidulina crassa* D'ORBIGNY, accounting for 1—26 per cent. In one sample *Virgulina* cf. *davisi* CHAPMAN and PARR was more frequent than *Cassidulina crassa*, and in another *Astrononion gallowayi* LOEBLICH and TAPPAN was second in number. In both of these samples the frequency of *C. crassa* was relatively low. *Nonion labradoricum* (DAWSON) should be regarded as the third charac-

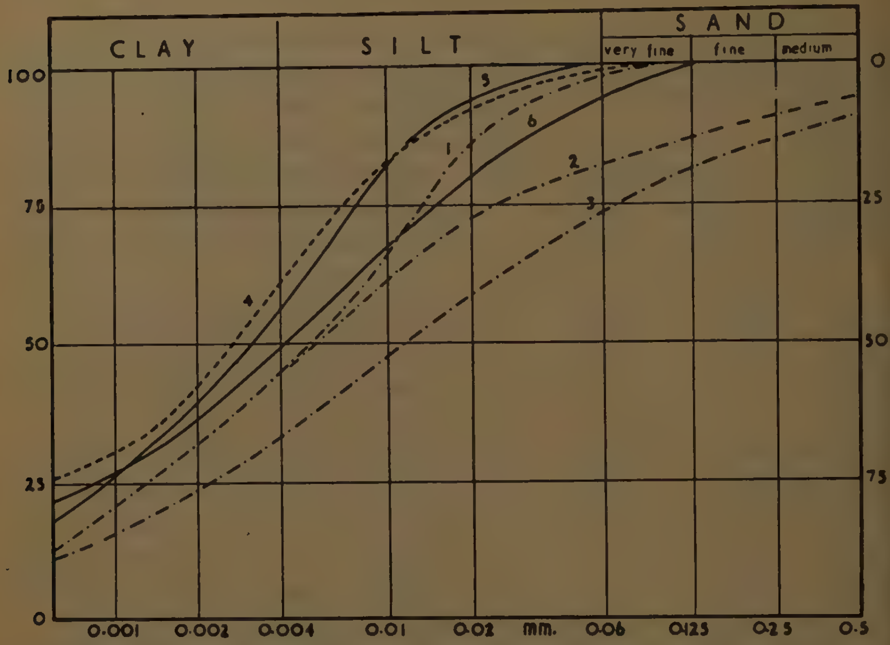

Fig. 2. Cumulative-frequency curves of some samples: 1, *Yoldia*-clay, Valle, Sarpsborg (Spl. nr. 1014); 2, *Yoldia*-clay, Korshavn, Hvaler (Spl. nr. 1016); 3, *Yoldia*-clay, Jomfruland (Spl. nr. 1017); 4, *Arca*-clay, Konowsgt. 66, Oslo (Spl. nr. 1124); 5, *Isocardia*-clay, Monradsgt, Oslo (Spl. nr. 1028); 6, *Isocardia*-clay, Borregård, Sarpsborg (Spl. nr. 1109).

teristic species. It was quite well represented in five samples, absent in two, and represented only by a single specimen in one sample. *Cibicides lobatulus* (WALKER and JACOB) was present in all samples, represented by large but usually few specimens.[1] *Astrononion gallowayi* LOEBLICH and TAPPAN were present in all samples but one.

These five species appear to be characteristic of the *Yoldia*-clay of the Oslofjord area. Their average frequency was:

Elphidium incertum clavatum CUSHMAN	72	per cent
Cassidulina crassa D'ORBIGNY	13	- -
Nonion labradoricum (DAWSON)	7	- -
Cibicides lobatulus (WALKER and JACOB)	2	- -
Astrononion gallowayi LOEBLICH and TAPPAN	2	- -

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[1] Samples of *Yoldia*-clay from shallower waters may probably contain more of this species.

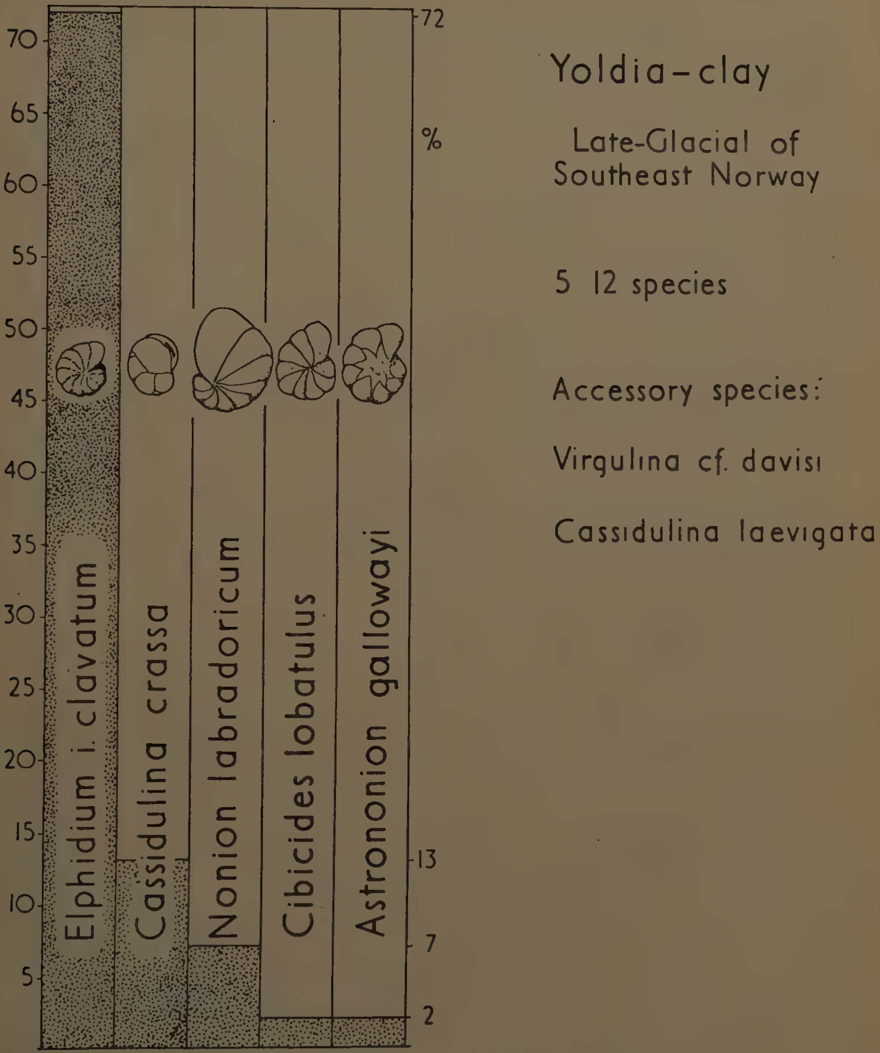

Fig. 3. The average frequency of five characteristic species of Foraminifera in *Yoldia*-clay.

Among the accessory species were *Virgulina* cf. *davisi* CHAPMAN and PARR and *Cassidulina laevigata* D'ORBIGNY. A more occasional occurrence had: *Quinqueloculina stalkeri* LOEBLICH and TAPPAN, *Quinqueloculina seminulum* (LINNAEUS), *Triloculina trihedra* LOEBLICH and TAPPAN, *Pyrgo* sp.[1], *Lagena squamosa* (MONTAGU) *Lenticulina* sp. juv., *Guttulina lactea, Elphidium incertum incertum* (WILLIAMSON), *Elphidium incertum selseyensis* (HERON-ALLEN and EARLAND). In two of the samples there was a single specimen of *Bulimina marginata* D'ORBIGNY most probably due to contamination. In one sample a single *Globigerina* was observed.

Thus the foraminiferal faunas of the *Yoldia*-day are distiguished by: a pronounced dominance of *Elphidium incertum clavatum*, a frequent occurrence of *Cassidulina crassa*, and a few specimens of *Astrononion gallowayi;* furthermore *Nonion labradoricum* is fairly common in most samples, and in some also *Cibicides lobatulus.*

KIÆR (1900, p. 53) has from a sample of «The old glacial clay, near Moss» listed 15 species, *Elphidium incertum clavatum* (recorded as *Polystomella striatopunctata* PARKER & JONES var. *incerta*) being the most frequent. Among the other species occurred: *Cassidulina crassa, C. laevigata, Quinqueloculina seminulum* (= *Miliolina seminulum*), *Pyrgo simplex* (= *Biloculina simplex*), *Nonion labradoricum* (= *Nonionina scapha*), all of them indicated by (n) (= a few). From a sample of *Yoldia*-clay from Verlebukten by Moss KIÆR listed (Cf. BRØGGER, 1900—1901, p. 33) 13 species, that fauna too being dominated by *E. incertum clavatum* and having the same accessory species as the sample just mentioned (*C. laevigata* absent). MADSEN (1895, pp., 156—57) found that *Polystomella striatopunctata* var. *incerta* occurred in all Danish Pleistocene strata investigated by him, but that it was very frequent only in deposits with an arctic or boreal fauna. Otherwise he regarded *Elphidiella arctica* (= *Polystomella arctica*) as index fossil for arctic and boreal sediments.

From a sample of *Yoldia*-clay from the island Tjørn in Bohuslän (Southwest Sweden) MUNTHE (1896, pp. 35—36) listed a foraminiferal fauna in which *Cassidulina laevigata, C. crassa, Cibicides lobatulus* (= *Planorbulina lobatula*), *Elphidium incertum* and *clavatum* (= *Poly-*

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[1] Specific determination of the *Pyrgo* species has as yet not been undertaken.

stomella striatopunctata), and *Nonion labradoricum* (= *Nonionina scapha*) were commonly represented, and in which *Astrononion gallowayi* (= *Nonionina stelligera*) occurred.

The foraminiferal faunas from *Yoldia*-clay of Vestgötaslätten (Munhte, 1901, p. 132) seem not to be consistent with the *Yoldia*-faunas from the Oslofjord area.

Brotzen (1951, p. 62) in the deeper part of a boring through the Pleistocene deposits at Surte near Gothenburg obtained foraminiferal faunas which were dominated by *E. incertum clavatum*, those parts of the core thus probably being referrable to the *Yoldia*-clay of the Oslofjord area. From examinations of various samples from the Swedish Pleistocene Brotzen (l. c. p. 59) concluded that there was in Late-Glacial sediments a pronounced predominance of *E. i. clavatum*, *C. crassa*, and *E. i. incertum*.

Hessland (1943) from none of his numerous samples from Bohuslän obtained a foraminiferal fauna which compare with that of the *Yoldia*-clay from the Oslofjord area. The mollusk faunas from his oldest samples show that they are of younger origin than the *Yoldia*-clay.

The Arca-clay.

In the *Arca*-clay the frequency distribution of the Foraminifera was less constant and the predominances less pronounced. Six samples of *Arca*-clay were examined.

Sample nr. 1022 from Hauketo station east of Ljan.
— - 1023 - Tuengen (V. Aker), Oslo.
— - 1033 - Lillo (V. Aker), Oslo.
— - 1101 - Grorud station by Oslo.
— - 1116 - Sandefjord.
— - 1124 - Konowsgate 66, Oslo.

Two of them, nr. 1033 and nr. 1101, were sterile. From the remaining four samples, between 200 and 600 specimens were picked out in each one. The number of species was somewhat larger than in the *Yoldia*-clay: two samples contained 11 species each, one contained 13, and one 17 species.

In all four samples *Elphidium incertum clavatum* Cushman and *Cassidulina crassa* d'Orbigny dominated the faunas. In two of them there were more *E. incertum clavatum* than *C. crassa* and in the other two *C. crassa* outnumbered *E. i. clavatum*. In all samples there was a fairly frequent occurrence of *Pullenia quinqueloba minuta* subsp.n. The presence of *Pullenia quinqueloba minuta* seems to distinguish the *Arca*-clay from the *Yoldia*-clay. In three of the samples this species was number three in frequency; in the fourth there was more specimens of *Virgulina* cf. *davisi* Chapman and Parr. *Virgulina* cf. *davisi* and *Elphidium incertum incertum* (Williamson) occurred in all samples, and *Cassidulina laevigata* d'Orbigny in three of them.

The average frequency of these six species was:

Elphidium incertum clavatum Cushman	47	per cent
Cassidulina crassa d'Orbigny	28	- -
Virgulina cf. *davisi* Chapman and Parr	4	- -
Pullenia quinqueloba minuta subsp.n.	4	- -
Cassidulina laevigata d'Orbigny	3	- -
Elphidium incertum incertum (Williamson)	3	- -

Among the accessory species were *Cibicides lobatulus* (Walker and Jacob) and *Lagena elongata distoma* Parker and Jones. Occasionally there occurred *i.a. Rheophax* sp., *Quinqueloculina stalkeri* Loeblich and Tappan, *Quinqueloculina seminulum* (Linnaeus), *Pyrgo* sp., *Dentalina* sp. juv., *Lagena striata substriata* (Williamson), *Lenticulina* sp. juv., *Virgulina fusiformis* (Williamson), *Elphidium incertum selseyensis* (Heron-Allen and Earland). In one sample there was a specimen of *Astrononion gallowayi* Loeblich and Tappan.

The foraminiferal characteristics of the *Arca*-clay thus seem to be: a frequent occurrence of *Elphidium incertum clavatum* and *Cassidulina crassa*, and *Pullenia quinqueloba minuta* as index fossil.

Kiær (1900, p. 53) listed 16 species of Foraminifera from a sample of *Arca*-clay from Svenengen, Oslo, amongst them being *Cassidulina crassa*, *C. laevigata*, *Nonion labradoricum* (= *Nonionina scapha*), *Elphidium i. clavatum* (= *Polystomella striatopunctata* var. *incerta*), and also *Pullenia spaeroides*. Reexamination of Kiær's sample, which is stored in the Paleontological Museum of Oslo, revealed that his *Pullenia sphaeroides* is identical with *Pullenia quinqueloba*

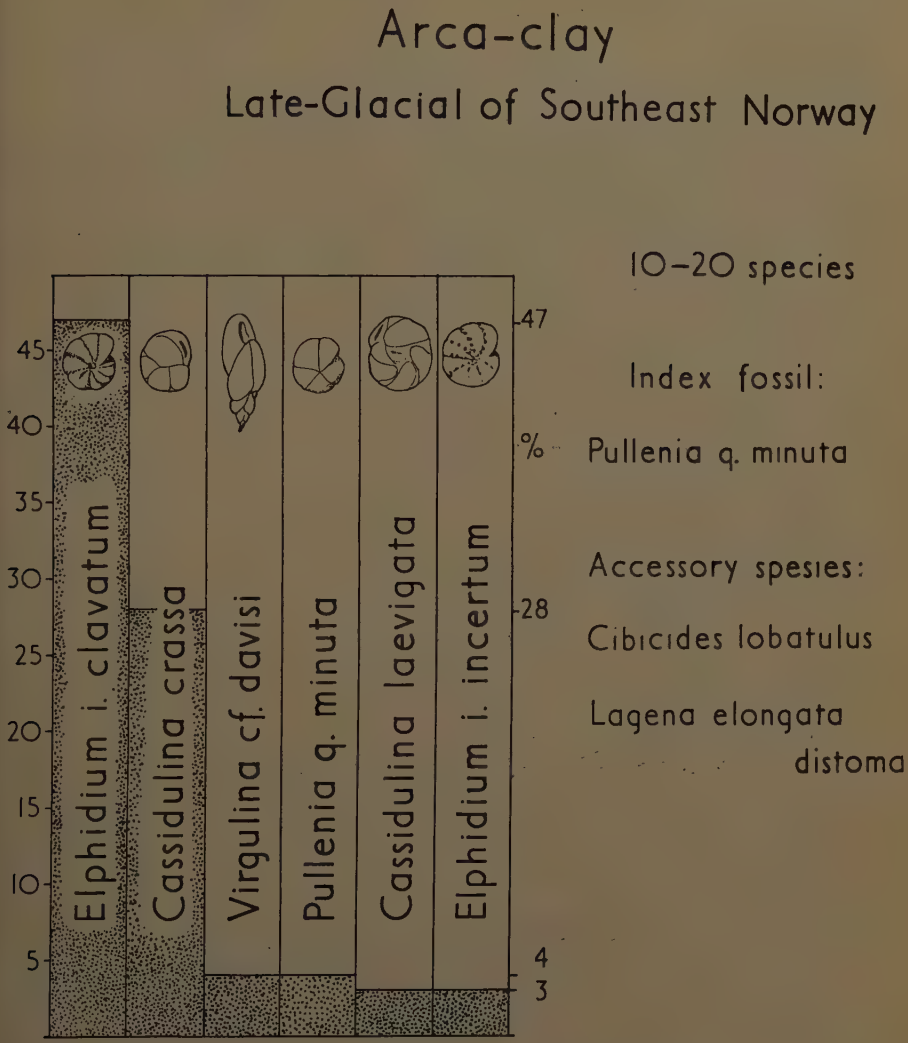

Fig 4. The average frequency of six characteristic species of Foraminifera in *Arca*-clay.

minuta subsp.n. In another list of Foraminifera from a sample of *Arca*-clay from Øvre Foss, Oslo, *Pullenia* is lacking (KIÆR in BRØGGER, 1900—1901, pp. 161—62). A few *Lagena elongata distoma* occurred;

many of the listed *Virgulina schreibersiana* are more referrable to *V.* cf. *davisi.*

Transitional sediments.

The *Mytilus-* and *Cyprina*-clay, the *Cardium*-clay, and the *Ostrea*-clay have not as yet been sufficiantly investigated to allow general conclusions.

The following four samples of clay with *Mytilus edulis*, dating from the transitional period between Late-Glacial and Post-Glacial age were examined:

Sample nr. 1030 from Strømmen near Oslo.
— - 1032 - Vettakollen, Oslo, 188 m above sea-level.
— - 1106 - Holmenkollen, Oslo, 202 m a. sea-level.
— - 1118 - Lund, Idd, near Halden, 117 m a.s.-l.

The sample from Strømmen (1030) contained no foraminifera, and the others were rather poor in specimens. The number of species was, 5 in samples nr. 1106, 9 in sample nr. 1032, and 20 in 1118. *Elphidium* was the most common genus. *Elphidium asterizans* (Fichtel and Moll) dominated in sample 1032, *E. incertum clavatum* Cushman in sample 1106, and *E. i. selseyensis* (Heron-Allen and Earland) in 1118. *E. i. incertum* (Williamson) was present in all of them (57 specimens in nr. 1032). *E. depressulum* (Walker and Jacob) occurred in two of the samples, *E. orbiculare* (H. B. Brady) and *E. excavatum* (Terquem) in one of them. Quite large and compressed specimens of *Elphidiella arctica* (Parker and Jones) occured in two of the samples, and *Buccella frigida* (Cushman) in one. In the sample from Lund in Idd *Cassidulina crassa* D'Orbigny, *Nonion labradoricum* (Dawson), and *Cibicides lobatulus* (Walker and Jacob) were quite frequent. They did not occur in the other samples, except for 1 specimen of *C. crassa* in nr. 1032. *Discorbis globularis* (D'Orbigny) occurred in two of the samples, and *Patellina corrugata* Williamson in one of them (1118). In all samples there were some ostracods and numerous *Mytilus-* and *Balanus*-fragments.

A frequent occurrence of different *Elphidium* species is probably characteristic of the *Mytilus*-clays.

A sample from Jessheim (nr. 1105), 35 km northeast of Oslo, yielded 11 specimens of *Elphidium incertum clavatum* and some ostracods.

A quite rich foraminiferal fauna (600 specimens) of a sample of *Cardium*-clay from Frogner, Oslo (1108), was dominated by *Virgulina fusiformis* (WILLIAMSON), this species accounting for 75 per cent of the fauna, with *Bulimina marginata* D'ORBIGNY and *Elphidium incertum incertum* (WILLIAMSON) quite abundantly represented. 9 specimens of *Lagena elongata distoma* PARKER and JONES, 7 of *Eponides exiguus* (H. B. BRADY), and 5 of *Nonionella turgida* (WILLIAMSON) were also present.

Two samples, nr. 1110 from Sandefjord and nr. 1112 from Nabbetorp by Fredrikstad, contained numerous valves of *Cyprina islandica* LINNEAUS and also of *Aloides gibba* (OLIVI) (= *Corbula gibba* (OLIVI)). A third sample, nr. 1123 from Sorgenfri clay pit by Fredrikstad, contained valves and fragments of *Ostrea edulis*, *Cyprina islandica*, *Aloides gibba*, and *Nassa reticulata* LINNAEUS. The foraminiferal faunas of these three samples were dominated by the agglutinated form *Verneuilina media* HÖGLUND; *Streblus beccarii* (LINNAEUS) was quite common, and *Bulimina marginata* D'ORBIGNY and *Elphidium excavatum* (TERQUEM) occurred.

Another sample, nr. 1114 from Borregård, Sarpsborg, contained numerous valves and fragments of *Ostrea edulis*, and compartments and fragments of *Balanus balanus* (LINNAEUS) and *B. crenatus* (BRUGUIERE). Its foraminiferal fauna was dominated by *Streblus beccarii*; second in order was *Cibicides lobatulus*, and third *Elphidium incertum selseyensis*.

All these four samples should probably be referred to BRÖGGER'S *Ostrea*-clay. They represent sediments which introduce the Post-Glacial warm period. Their foraminiferal faunas have, however, certain facial components which partly obliterate their stratigraphic indications. From further investigations we will learn to distinguish the main features of the faunas from facial anomalies.

The Isocardia-clay.

The *Isocardia*-clay of the Post-Glacial warm period is clearly defined by its Foraminifera. Six samples, in part from widely separated localities within the Oslofjord area have been examined:

Sample nr. 1025 from Årum by Sarpsborg.
— - 1028 - Monradsgate, Oslo.
— - 1100 - Svenengen, Oslo.
— - 1109 - Borregård, Sarpsborg.
— - 1113 - Valle by Sarpsborg.
— - 1117 - Porsnes by Halden.

They were all rich both in species and specimens. In three of the samples, more than 1200 specimens were picked out in each one, and in the other three, less than 750 in each. Four of the samples yielded more than 20 species, one of them 16, and one 14. The maximum number of species in one sample was 28.

In all samples of *Isocardia*-clay there was a pronounced predominance of *Bulimina marginata* D'ORBIGNY, this species accounting for 35—60 per cent of the faunas (the percentages were: 35—48—52—59—60—60). In all samples but one, *Elphidium incertum incertum* (WILLIAMSON) came second in frequency, accounting for 11—34 per cent of the faunas. In one sample, *Nonion pompilioides* (FICHTEL and MOLL) was more frequent than *E. i. incertum*. In three samples, *Nonion pompilioides* came third in frequency; in one it was lacking, and in another it was outnumbered by *Virgulina fusiformis* (WILLIAMSON). *Virgulina fusiformis* was present in five samples and *Elphidium incertum selseyensis* (HERON-ALLEN and EARLAND) was present in all of them. *Cassidulina laevigata* D'ORBIGNY was quite common in most of the samples, and also *Elphidium incertum clavatum* CUSHMAN.

The average percentages of the frequency of these seven species were:

Bulimina marginata D'ORBIGNY	52	per cent
Elphidium incertum incertum (WILLIAMSON)	15	- -
Nonion pompilioides (FICHTEL and MOLL)	7	- -
Cassidulina laevigata D'ORBIGNY	4	- -
Elphidium incertum clavatum CUSHMAN	3	- -
Elphidium i. selseyensis (HERON-ALLEN and EARLAND)	2	- -
Virgulina fusiformis (WILLIAMSON)	2	- -

Among the accessory species were usually: *Rheophax subfusiformis* EARLAND, *Eponides exiguus* (H. B. BRADY), *Nonionella turgida* (WILLIAMSON), and *Streblus beccarii* (LINNAEUS).

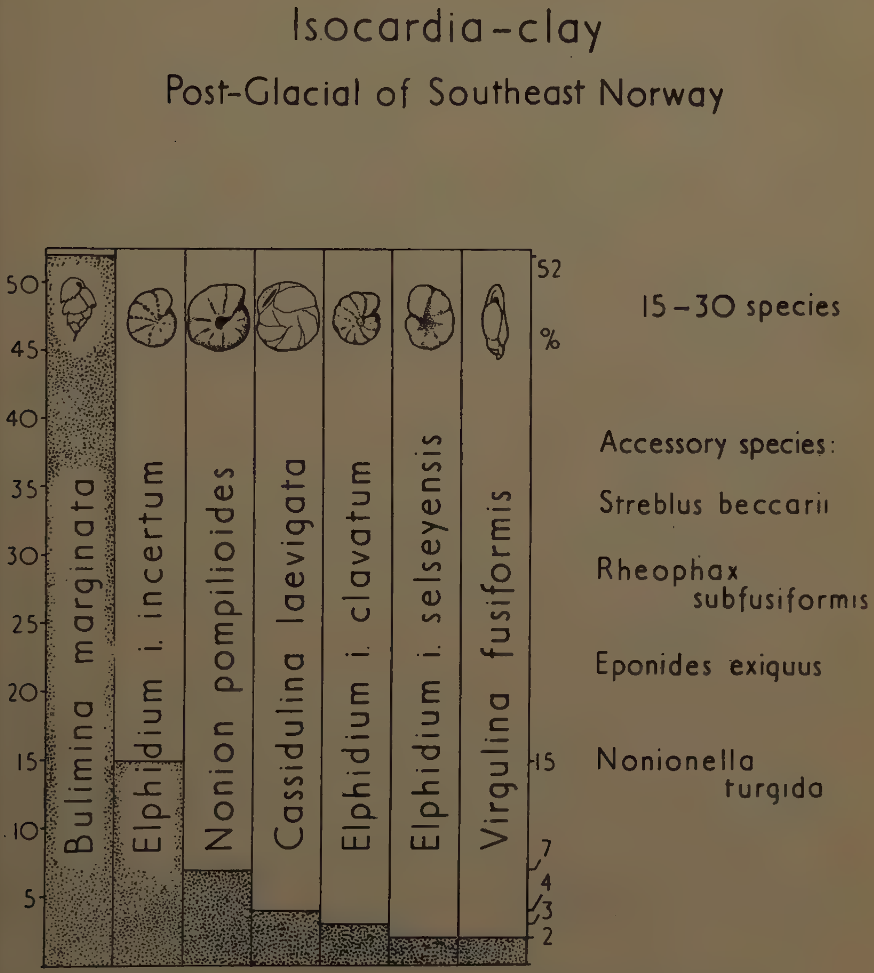

Fig. 5. The average frequency of seven characteristic species of Foraminifera in *Isocardia*-clay.

The following had an intermittent occurrence: *Saccammina sphaerica* G. O. SARS, *Textularia bocki* HÖGLUND, *T. sagittula* DEFRANCE, *Verneuilina media* HÖGLUND, *Quinqueloculina fusca* H. B. BRADY, *Q. contorta* D'ORBIGNY, *Q. seminulum* (LINNAEUS), *Triloculina circularis* (BORNEMANN), *T. trigonula* (LAMARCK), *Pyrgo* sp., *Ophthalmidium inconstans* (H. B. Brady), *Lagena apiculata* (Reuss), *L. elongata elongata* (Ehrenberg), *L. elongata distoma* Parker and Jones, *L. gracillima* (Seguenza), *L. hexagona* (Williamson), *L. laevis* (Montagu), *L. striata striata* (D'Orbigny), *L.striata substriata* (Williamson), *Guttulina* sp. juv., *Globobulimina turgida* (Bailey), *Uvigerina peregrina* Cushman, *Bolivina* sp. juv., *Cassidulina crassa* D'Orbigny, *Discorbis globularis* (D'Orbigny), *Eponides* sp., *Cibicides lobatulus* (Walker and Jacob), *C. pseudoungerianus* (Cushman), *Anomalina balthica* (Schroeter), *Planorbulina mediterranensis* D' Orbigny, *Nonion labradoricum* (Dawson), and *Elphidium excavatum* (Terquem).

The characteristics of the foraminiferal faunas of the *Isocardia*-clay of the Oslofjord area thus seem to be: A pronounced predominance of *Bulimina marginata* and a rather frequent occurrence of *Elphidium i. incertum* and also of *Nonion pompilioides*. In addition some specimens of *Streblus beccarii* will be present.

Kiær (1900, p. 53) listed 5 species of foraminifera from *Isocardia*-clay from Svenengen, Oslo, amongst them being *Bulimina marginata.* M. Sars (1865, p. 91) listed *B. marginata* (= *Bulimina presli* var. *marginata*) from a few samples of *Isocardia*-clay; but he found *Nonion pompilioides* (= *Nonionina umbilicatula*) to be more frequent. Both Crosskey and Robertson (1868) and Münster (ms., in part printed in Brögger, 1900—1901) examined *Isocardia*-bearing clay samples, but as their samples have not been kept duly apart from the underlying *Arca*-clay, their listed fossils are of little interest (Cf. Brögger, 1900—1901, p. 472). Crosskey and Robertson (1868) recorded *Bulimina marginata* from four localities, but with no indications of its frequency.

Zone 7 in the diagram of the Surte boring (Brotzen, 1951, p. 62) corresponds fairly well with the *Isocardia*-clay of the Oslofjord area, especially at core level 3 m.

Hessland (1943) has not recorded *Bulimina marginata* from his *Isocardia*-clays but *Nonion pompilioides* occurred in all of them.

Two samples of *Scrobicularia*-clay from different places in Oslo,

Sample nr. 1027 from Nybrua, Oslo.
— - 1029 — Stensgaten, Oslo.

contained only a few arenaceous forms, *Verneuilina media* HÖGLUND, *Eggerella scabra* (WILLIAMSON), and *Valvulina fusca* (WILLIAMSON) being the most frequent.

The Foraminifera.

Psammosphaera fusca SCHULZE, 1875

SCHULZE, 1875, p. 113, pl. 2, figs. 8a-f.
HÖGLUND, 1947, p. 46, pl. 4, figs. 9—14.

One specimen occurred in *Ostrea*-clay, sample nr. 1123 from Sorgenfri by Fredrikstad.

Saccammina sphaerica G. O. SARS, 1871.

SARS, G. O. 1871, p. 250.
HÖGLUND, 1947, p. 50, pl. 4, figs. 15—17.

One specimen in *Isocardia*-clay (nr. 1113) and one in *Ostrea*-clay (nr. 1123).

Rheophax subfusiformis EARLAND, 1933.

Plate I, fig. 1.

EARLAND, 1933, p. 74, pl. 2, figs. 16—19.
HÖGLUND, 1947, p. 82, pl. 9, figs. 1—4; pl. 26, figs. 1—19; text-figs. 43—50.

104 specimens were picked out of a sample of *Isocardia*-clay from Årum by Sarpsborg (nr. 1025), and 1 specimen from *Isocardia*-clay from Svenengen, Oslo (nr. 1100). The species probably occurs in many other localities too but due to its fragility it may be represented only by indeterminable fragments.

Rheophax sp.

A few fragments present in most samples of Post-Glacial age; one fragment in a sample of *Arca*-clay from Tuengen, Oslo (nr. 1023).

Ammoscalaria runiana (HERON-ALLEN and EARLAND, 1916).

Haplophragmium runianum HERON-ALLEN and EARLAND, 1916, p. 224, pl. 40, figs. 15—18.
Ammoscalaria runiana, HÖGLUND, 1947, p. 162, pl. 9, figs. 23, 24; text-fig. 137.

8 more or less broken specimens occurred in a sample with *Cyprina islandica* from Stein clay pit at Sandefjord (nr. 1110).

Textularia bocki Höglund, 1947.

Höglund, 1947, p. 171, pl. 12, figs. 5—7; text-figs. 152, 153.

One specimen occurred in a sample of *Isocardia*-clay from Årum by Sarpsborg (nr. 1025).

Textularia sagittula Defrance, 1824.

Defrance, 1824, p. 177.
Höglund, 1947, p. 167, pl. 12, figs. 3, 4; text-figs. 143—146.

One specimen in *Isocardia*-clay from Årum (nr. 1025).

Verneuilina media Höglund, 1947.

Höglund, 1947, p. 184, pl. 13, figs. 7—10; pl. 30, fig. 21.

Description (after Höglund, l. c.). «Test small, elongate, 1½ 2½ times as long as broad, triserial throughout, proloculum apical; chambers not very numerous (about 15), weakly inflated, about twice as broad as high, their longitudinal axis making an acute angle with the long axis of the test; sutures usually indistinct especially in the earliest part of the test; wall coarsely arenaceous, made up of very large mineral grains (sometimes as large as the breadth of the test) firmly cemented together, exterior very rough and often irregular owing to the large sand grains; aperture interiomarginal, loop-shaped, at the inner margin of the last chamber, with a small, raised lip at one side; colour ferruginous or white. Size. Length about 0,35 mm; breadth up to 0,24 mm.»

This species dominated the foraminiferal faunas of three samples with *Cyprina islandica* (nr. 1110, 1112, 1123), these samples probably being referrable to Brögger's *Ostrea*-clay. 157 specimens occurred also in a sample of *Isocardia*-clay from Valle by Sarpsborg (nr. 1113), and some in a sample of *Scrobicularia*-clay from Oslo (nr. 1029).

Eggerella scabra (Williamson, 1858).

Bulimina scabra Williamson, 1858, p. 65, pl. 5, figs. 136, 137.

Eggerella scabra, CUSHMAN, 1937, p. 50, pl. 5, figs. 10, 11.
HÖGLUND, 1947, p. 191, pl. 13, figs. 12—14; text-figs. 162—165.

A few specimens present in a sample of *Scrobicularia*-clay from Oslo (nr. 1029).

Valvulina fusca (WILLIAMSON, 1858).

Rotalina fusca WILLIAMSON, 1858, p. 55, pl. 5, figs. 114, 115.
Valvulina fusca, H. B. BRADY, 1884, p. 392, pl. 49, figs. 13,14.
HÖGLUND, 1947, p. 190, pl. 14, fig. 2; text-figs. 173—176.

Some specimens occurred in a sample of *Scrobicularia*-clay from Oslo (nr. 1027).

Quinqueloculina fusca H. B. BRADY, 1870.

H. B. BRADY, 1870, p. 286, pl. 11, fig. 2.
CUSHMAN, 1929, p. 23, pl. 1, figs. 4a-c.

Two specimens from a sample of *Isocardia*-clay (nr. 1100). Its main recent distribution seems to be: Lusitanian parts of the eastern Atlantic.

Quinqueloculina stalkeri LOEBLICH and TAPPAN, 1953.

Plate I, figs. 2a, b.

LOEBLICH and TAPPAN, 1953, p. 40, pl. 5, figs. 5—9.

A few specimens present in *Arca*-clay (nr. 1124, 1116) and one in *Yoldia*-clay (nr. 1016). Its main recent distribution is arctic.

Quinqueloculina seminulum (LINNAEUS, 1767).

Plate I. figs. 3a, b.

Serpula seminulum LINNAEUS, 1767, p. 1264.
Quinqueloculina seminulum, D'ORBIGNY, 1826, p. 303.
Miliolina seminulum, WILLIAMSON, 1858, p. 85, pl. 7, figs. 183—185.
Quinqueloculina seminulum, CUSHMAN, 1929, p. 24, pl. 2, figs. 1, 2.

Present in most of the samples; more common in Post-Glacial sediments than in Late-Glacial ones.

Quinqueloculina contorta D'ORBIGNY, 1846.

Quinqueloculina contorta D'ORBIGNY, 1846, p. 298, pl. 20, figs. 4—6.
Miliolina contorta, H. B. BRADY, 1887, p. 881.

Quinqueloculina contorta, CUSHMAN, 1929, p. 29, pl. 3, figs. 6a-c.

One specimen in *Isocardia*-clay from Svenengen, Oslo.

Triloculina trigonula (LAMARCK, 1804).

Miliolites trigonula LAMARCK, 1804, p. 351.
Triloculina trigonula, D'ORBIGNY, 1826, p. 299, pl. 16, figs. 5—9.
CUSHMAN, 1929, p. 56, pl. 12, figs. 10, 11; pl. 13, figs. 1, 2.

One specimen in a sample of *Isocardia*-clay (nr. 1113).

Triloculina trikedra LOEBLICH and TAPPAN, 1953.

Plate I, fig. 4.

Triloculina tricarinata, CUSHMAN, 1929, p. 56, pl. 13, figs. 3a-c.
HESSLAND, 1943, pl. 1, figs. 5 a, b.
Triloculina trihedra LOEBLICH and TAPPAN, 1953, p. 45, pl. 4, figs. 10 a, b.

One specimen in a sample of *Yoldia*-clay (nr. 1014).

Triloculina circularis BORNEMANN, 1855.

BORNEMANN, 1855, p. 349, pl. 19, figs. 4a-c.
CUSHMAN, 1929, p. 58, pl. 13, figs. 6, 7; pl. 14, figs. 1, 2.

Three samples of *Isocardia*-clay (nr. 1100, 1113, 1028) contained 1 or 2 specimens each.

Pyrgo sp.

Plate I, figs. 5a, b, 6.

A few specimens present in three samples of *Yoldia*-clay, one sample of *Arca-clay*, one sample of *Cardium*-clay, and three samples of *Isocardia*-clay.

Ophthalmidium inconstans (H. B. BRADY, 1879).

Plate I, figs. 7a, b.

Hauerina inconstans H. B. BRADY, 1879, p. 268.
Ophthalmidium inconstans, H. B. BRADY, 1884, p. 189, pl. 12, figs. 5, 7, 8.
CUSHMAN, 1929, p. 89, pl. 21, figs. 8—11.

Present in two samples of *Isocardia*-clay, 2 specimens in sample nr. 1109, and 9 in nr. 1113. Its main recent distribution seems to be lusitanian, fairly deep waters.

Dentalina sp.

One broken specimen in a sample of *Arca*-clay.

Lagena apiculata (Reuss, 1850).

Oolina apiculata Reuss, 1850, p. 22, pl. 1, fig. 1.
Lagena apiculata, Reuss, 1862, p. 319, pl. 1, figs. 4—8, 10, 11.
Cushman, 1923, p. 7, pl. 1, fig. 5.

One specimen in a sample of *Isocardia*-clay (nr. 1100).

Lagena elongata elongata (Ehrenberg, 1844).

Plate I, fig. 8.

Miliola elongata Ehrenberg, 1844, p. 274.
Lagena elongata, Tate and Blake, 1876, p. 454, pl. 18, figs. 9, 9a.
Cushman, 1923, p. 15, pl. 3, fig. 4.

Present in two samples of *Isocardia*-clay, 1 specimen in each one.

Lagena elongata distoma Parker and Jones, 1864.

Plate I, fig. 9.

Lagena distoma Parker and Jones in H. B. Brady, 1864, p. 467, pl. 48, fig. 6.
Brady, 1884, p. 461, pl. 58, figs. 11—15.
Cushman, 1923, p. 14, pl. 3, figs. 2, 3.
Lagena elongata distoma, Hessland, 1943, p. 262, pl. 2, fig. 28.

Some specimens occurred in three samples of *Arca*-clay, 9 specimens in a sample of *Cardium*-clay (nr. 1108), and a few specimens were present in most samples of *Isccardia*-clay.

Lagena gracillima (Seguenza, 1862).

Amphorina gracillima Seguenza, 1862, p. 51, pl. 1, fig. 37.
Lagena gracillima, Jones, Parker, and Brady, 1866, p. 45, pl. 1, figs. 36, 37.
Cushman, 1923, p. 23, pl. 4, fig. 5.

One specimen in a sample of *Isocardia*-clay (nr. 1028).

Lagena hexagona (Williamson, 1848).

Entosolenia squamosa Montagu, var. *hexagona* Williamson, 1848, p. 20, pl. 2, fig. 23.

Lagena hexagona, Siddal, 1879, p. 6.
Cushman, 1923, p. 24, pl. 4, fig. 6.

Two specimens in a sample of *Isocardia*-clay (nr. 1028).

Lagena laevis (Montagu, 1803).

Vermiculum læve Montacu, 1803, p. 524.
Lagena laevis, Williamson, 1848, p. 12, pl. 1, figs. 1, 2.
Brady, 1884, p. 455, pl. 56, figs. 7—9.
Cushman, 1923, p. 29, pl. 5, fig. 3.
Cushman and McCulloch, 1950, p. 341, pl. 45, figs. 14—16.

One specimen in a sample of *Isocardia*-clay (nr. 1025).

Lagena squamosa (Montagu, 1803).

Vermiculum squamosum Montagu, 1803, p. 526, pl. 14, fig. 2.
Lagena squamosa, Brown, 1844, pl. 1, fig. 32.
Cushman, 1923, p. 51, pl. 10, figs. 3, 4.
Hessland, 1943, pl. 2, figs. 32, 33.

This species occurred in two samples of *Yoldia*-clay, 2 specimens in sample nr. 1014, and 1 in nr. 1016. Its main recent distribution is: Arctic and boreal parts of the North Atlantic (Cf. Nörvang, 1945, p. 22).

Lagena striata striata (D'Orbigny, 1839).

Oolina striata D'Orbigny, 1839, p. 21, pl. 5, fig. 12.
Lagena striata, Reuss, 1862, p. 327, pl. 3, figs. 44, 45.
Cushman, 1923, p. 54, pl. 10, fig. 9.

Two specimens in a sample of *Isocardia*-clay (nr. 1028).

Lagena striata substriata (Williamson, 1848).

Lagena substriata Williamson, 1848, p. 15, pl. 1, fig. 12.
Cushman, 1923, p. 56, pl. 10, fig. 11.
Lagena striata (D'Orbigny) cf. var. *substriata*, Hessland, 1943, p. 263, pl. 2, figs. 20a, b.
Lagena substriata, Voorthuysen, 1950b, pl. 1, fig. 9.

Occurred in two samples of *Arca*-clay, 2 specimens in sample nr. 1023, and 1 in nr. 1116; it occurred also in two samples of *Isocardia*-clay, 2 specimens in sample nr. 1100, and 1 in nr. 1028.

Lenticulina sp. juv.

1 specimen from *Yoldia*-clay, 1 from *Arca*-clay, and three from *Isocardia*-clay. The *Yoldia*-clay specimen had much in common with *Lenticulina thalmanni* (HESSLAND, 1943).

Guttulina lactea (WALKER and JACOB, 1798).

Serpula lactea WALKER and JACOB, 1798, p. 634, pl. 14, fig. 4.
Guttulina lactea, OZAWA, 1929, p. 36, pl. 6, figs. 6—10.
CUSHMAN and OZAWA, 1930, p. 43, pl. 10, figs. 1—4.

1 specimen from *Yoldia*-clay, and 1 from *Mytilus*-clay.

Guttulina sp. juv.

1 specimen from *Isocardia*-clay.

Bulimina marginata D'ORBIGNY, 1826.

Plate I, figs. 10 a, b.

D'ORBIGNY, 1826, p. 269, pl. 12, figs. 10—12.
HÖGLUND, 1947, p. 227, pl. 20, figs. 1, 2; pl. 22, fig. 1; text-figs. 205—218.

Description: (mainly after HÖGLUND, l. c.). Test ovate, tapering usually broadest near the apertural end; chambers numerous, inflated, all visible from the exterior, arranged in a triserial spiral; the lower margin of the chambers usually extending out from the preceding at a definite acute angle and forming a sharpened boarder, which may be armed with denticles or spines of varying length; the armature may be present on all chambers or limited to the earliest ones, or may exceptionally be totally absent; sutures distinct, depressed; wall in the earliest part of the test thick, white, and opaque, in the younger part thinner and semitransparent, densely perforated with extremely fine pores; aperture fairly large with a raised collar on one side and on the other with a descending, folded tongue connected with the tongue of the preceding chamber, thus forming a complicated internal trough system. Length up to 0,7 mm; breadth about half the length in adults, comparatively greater in young specimens.

Occurence: This species was very abundant in the *Isocardia*-clay dominating the faunas in all the samples. In sample nr. 1025, from Årum, 725 specimens were picked out, in sample nr. 1100, from

Svenengen, 745 specimens, and in nr. 1028, from Monradsgate, Oslo, 850 specimens were picked out. It was very sparingly represented in two samples of *Ostrea*-clay (nr. 1110 and 1112), and quite abundantly in a sample of *Cardium*-clay from Oslo. It occurred in a sample of *Arca*-clay and single specimens were observed in two samples of *Yoldia*-clay, these occurrences in Late-Glacial sediments most probably being due to contamination. — Its main recent distribution seems to be temperate waters (Cf. NÖRVANG, 1945, p. 32).

Globobulimina turgida (BAILEY, 1851).

Plate I, fig. 11.

Bulimina turgida BAILEY, 1851, p. 12, pl. 0, figs. 28—31.
Bulimina marginata, PARKER and JONES, 1857, p. 296 (in part), pl. 11, figs. 36, 37.
Globobulimina turgida, HÖGLUND, 1947, p. 248, pl. 20, fig. 5; pl. 21, figs. 4—8; pl. 22, fig. 5; text-figs. 247—257, 271.

Occurred in two samples of *Isocardia*-clay, 8 specimens in sample nr. 1109, and 1 specimen in nr. 1028.

Virgulina cf. *davisi* CHAPMAN and PARR, 1937.

Plate I, figs. 12a, b.

CHAPMAN and PARR, 1937, p. 88, pl. 8, fig. 15.
HESSLAND, 1943, p. 267, pl. 4, figs. 48a, b.

Present in most samples of Late-Glacial age, quite frequent in the *Arca*-clay.

Virgulina fusiformis (WILLIAMSON, 1858).

Plate I, figs. 13a-c.

Bulimina pupoides var. *fusiformis* WILLIAMSON, 1858, p. 63, pl. 5, figs. 129—130.
«*Bulimina*» *fusiformis*, HÖGLUND, 1947, p. 232, pl. 20, fig. 3; text-figs. 219—233.

Present in most samples of Post-Glacial age, especially frequent in a sample of *Cardium*-clay (446 specimens), and quite common in the *Isocardia*-clay. A few specimens occurred in a sample of *Arca*-clay, probably due to contamination.

Uvigerina peregrina CUSHMAN, 1923.

Plate I, fig. 14.

CUSHMAN, 1923, p. 166, pl. 42, figs. 7—10.

HÖGLUND, 1947, p. 297, pl. 23, fig. 9; text-figs. 291—304.

A few specimens present in three samples of *Isocardia*-clay (nr. 1009, 1113, 1117). — Its main recent distribution is: The lusitanian and boreal parts of the Atlantic and the Pacific (NÖRVANG, 1945, p. 36).

Bolivina sp. juv.

One specimen in a sample of *Arca*-clay (nr. 1023), and one in a sample of *Isocardia*-clay (1113).

Cassidulina crassa D'ORBIGNY, 1839.

Plate II, figs. 1a, b.

D'ORBIGNY, 1839, p. 56, pl. 7, figs. 18—20.
CUSHMAN, 1922, p. 124, pl. 26, fig. 7.

This species was very frequent in all the samples of Late-Glacial age. It occurred also in two samples of *Mytilus*-clay, and a few specimens were present in five samples of *Isocardia*-clay.

Some of the specimens resemble the var. *reniforme* NÖRVANG, 1945, and some of them *Cassidulina islandica* NÖRVANG, 1945. They seem, however, to intermingle in the different samples, transitional forms between the var. *reniforme* and the typical *C. crassa*, and between this form and *C. islandica* being present.

Cassidulina laevigata D'ORBIGNY, 1826.

Plate II, figs. 2a, b.

D'ORBIGNY, 1826, p. 282, pl. 15, figs. 4, 5.
CUSHMAN, 1922, p. 122, pl. 24, fig. 4.
VOORTHUYSEN, 1950a, pp. 32, 39, pl. 2, fig. 2.

Usually large, translucent, glistening forms in the Late-Glacial clays, and small, partly opaque and partly carinated forms in the Post-Glacial ones. Quite common. — Its recent distribution seems to be cosmopolitan.

Pullenia quinqueloba minuta subsp. n.

Plate II, figs. 3a, b.

Pullenia bulloides, PARKER and JONES, 1857, p. 287, pl. 11, figs. 9, 10.
Pullenia sphaeroides, KIÆR, 1900, p. 53.

Description: Test small, close coiled, entirely involute, subspherical, compressed laterally, peripheral edge broadly rounded; chambers five in the last formed coil, slightly inflated; sutures correspondingly depressed, distinct; wall thin, semitransparent, finely perforate, surface smooth, shining; aperture an elongate, narrow semicircular slit at the base of the low apertural face. Diameter: 0,15 — 0,20 mm.

Holotype: Paleontological museum, Oslo, Fo. 1124a.

Type stratum and locality: *Arca*-clay from Konowsgate 66, Oslo.

Occurrence: Some specimens were present in all the four fossilbearing samples of *Arca*-clay from the Oslofjord area.

Remarks: This species has the appearence of a somewhat compressed *Pullenia sphaeroides* (D'ORBIGNY, 1826) with which it also agrees in size, the diameter of the adult test of *P.sphaeroides* according to BRADY (1884, p. 616) ranging from 0,17 to 0,34 mm (CUSHMAN, 1924, p. 41, writes «Diameter less than 0,50 mm»). It differs from *P. sphaeroides* in having 5 instead of 4 chambers in the last formed coil, and in having distinctly depressed sutures. It agrees with *P. quinqueloba* (REUSS, 1851) in having 5 chambers in the youngest whorl and in being laterally compressed. It differs from *P.quinqueloba* in its minute size and in its broadly rounded peripheral edge. In the original description of *P. quinqueloba* (REUSS, 1851, p. 71) the diameter is 0,3 mm; BRADY (1884, p. 617) writes «sometimes attains a diameter of 0,72 mm», and CUSHMAN (1924, p. 43) says up to 0,75 mm.

In CUSHMAN'S description (l. c. p. 42) the peripheral edge of *P. quinqueloba* is broadly rounded. This is in disagreement with the specific description given by REUSS (l. c.) where it is triangular (REUSS, 1851, p. 71, pl. 5, figs. 31a, b). The present subspecies has its position between the species of D'ORBIGNY and that of REUSS.

KIÆR (1900, p. 53) recorded one specimen of *P. spaeroides* from *Arca*-clay from Svenengen, Oslo (cf. also BRÖGGER, 1900—1901, p. 162). It is identical with *P. quinqueloba minuta* subsp.n. (cf. present paper p. 118). The species described and figured by PARKER and JONES (1857) also belongs to the present subspecies. It was rare in their Norway dredgings (l. c. p. 287).

Patellina corrugata WILLIAMSON, 1858.

WILLIAMSON, 1858, p. 46, pl. 3, figs. 86—89.
CUSHMAN, 1931, p. 11, pl. 2, figs. 6, 7.
LOBLICH and TAPPAN, 1953, p. 114, pl. 21, figs. 4—5.

Three specimens in a sample of *Mytilus*-clay from Lund in Idd.

Discorbis globularis (D'ORBIGNY, 1826).

Rosalina globularis D'ORBIGNY, 1826, p. 271, pl. 13, figs. 1, 2.
Discorbis globularis, CUSHMAN, 1931, p. 22, pl. 4, figs. 9a-c.
VOORTHUYSEN, 1950b, p. 64, pl. 3, figs. 8a-c.

A few specimens present in two samples of *Mytilus*-clay (sample nr. 1032 and 1118), and in three samples of *Isocardia*-clay (nr. 1109, 1113, and 1117).

Eponides exiguus (H. B. BRADY, 1884).

Plate II, figs, 4a, b.

Pulvinulina exigua H. B. BRADY, 1884, p. 696, pl. 103, figs. 13, 14.
Eponides exigua, CUSHMAN, 1931, p. 44, pl. 10, figs. 1, 2.
Eponides exiguus, THALMANN, 1932, p. 310.

Description: Test small, trochoid, dorsal side more convex than the ventral one, peripheral edge acute to bluntly rounded, peripheral margin very slightly lobulate, three whorls visible on the dorsal side; chambers six in the last formed whorl, most easily distinguished on the ventral side; sutures distinct, oblique and almost flush with the surface on the dorsal side, nearly radial and distinctly depressed on the ventral side; wall smooth, hyaline, perforate; aperture on the ventral margin of the youngest chamber. Diameter: up to 0,20 mm.

Remarks: The present species was quite common in the *Isocardia*-clay, being present in three samples; it occurred also in the sample of *Cardium*-clay. It is more in keeping with the description and figures of BRADY (1884) than with CUSHMAN's interpretation of the species (1931). Its diameter is smaller than those given by BRADY (0,4 mm or less) and CUSHMAN (0,3—0,5 mm). The species is widely distributed in fairly deep water in the Atlantic.

Eponides sp.

A broken specimen in *Isocardia*-clay (nr. 1109).

Bucella frigida (CUSHMAN, 1922).

Pulvinulina frigida CUSHMAN, 1922, p. 12.
Eponides frigida, CUSHMAN, 1931, p. 45.
Eponides frigidus, VOORTHUYSEN, 1949, p. 66, pl. 1, figs. 3a-c.
Bucella frigida, ANDERSEN, 1952, p. 144, figs. 4a-c, 6a-c.

Five specimens occurred in a sample of *Mytilus*-clay from Lund in Idd near Halden.

Cibicides lobatulus (WALKER and JACOB, 1798).

Plate II, figs. 5a, b.

Nautilus lobatulus WALKER and JACOB, 1798, p. 642, pl. 14, fig. 36.
Truncatulina lobatula, part of authors.
Cibicides lobatula, CUSHMAN, 1931, p. 118, pl. 21, figs. 3a-c.

This species was quite common in all samples of *Yoldia*-clay where it was represented by large and rather regular specimens. It was rare in the *Arca*-clay. It occurred in one sample of *Mytilus*-clay, in one sample of *Ostrea*-clay, and in three samples of *Isocardia*-clay. The specimens from *Isocardia*-clay were more flattened and their marginal outline more irregular and lobulate than those from Late-Glacial sediments.

It is common in cool waters attached to hydroid stems, algae etc. (CUSHMAN, 1931, p. 119; VOORTHUYSEN, 1949, p. 67). Otherwise its recent distribution is cosmopolitan.

Cibicides pseudoungerianus (CUSHMAN, 1922).

Truncatulina pseudoungeriana CUSHMAN, 1922, p. 97, pl. 20, fig. 9.
Cibicides pseudoungeriana, CUSHMAN, 1931, p. 123, pl. 22, figs. 3—7.

Present in two samples of *Isocardia*-clay, two specimens in nr. 1109, and one in nr. 1117.

Anomalina balthica (SCHROETER, 1783).

Nautilus balthicus SCHROETER, 1783, p. 20, pl. 1, fig. 2.
Operculina ammonoides, H. B. BRADY, 1884, p. 745, pl. 112, figs. 1a, b, 2.

Anomalina balthica, CUSHMAN, 1931, p. 108, pl. 19, figs. 3a-c.
Anomalina balthica (GRONOVIUS), THALMANN, 1932, p. 311.

A few specimens occurred in two samples of *Isocardia*-clay (sample nr. 1028, and 1109). — Its main recent distribution is: The boreal and lusitanian parts of the Atlantic and the Pacific (NÖRVANG, 1945, p. 48), most commonly met with in the eastern parts of the North Atlantic (CUSHMAN, 1931, p. 109).

Globigerina sp.

A single specimen observed in a sample of *Yoldia*-clay from Hvaler (nr. 1016).

Planorbulina mediterranensis D'ORBIGNY, 1826.

D'ORBIGNY, 1826, p. 280, pl. 14, figs. 4—6.
CUSHMAN, 1931, p. 129, pl. 24, figs. 5—8.

Two specimens from *Isocardia*-clay (sample nr. 1028). — Recent distribution: Boreal and lusitanian parts of the Atlantic and the Pacific (NÖRVANG, 1945, p. 51).

Nonionella turgida (WILLIAMSON, 1858).

Plate II, fig. 6.

Rotalina turgida WILLIAMSON, 1858, p. 50, pl. 4, figs. 95—97.
Nonionella turgida, CUSHMAN, 1930, p. 15, pl. 6, figs. 1—4.
CUSHMAN, 1939, p. 32, pl. 9, figs. 2, 3.

This small and characteristic form was quite common in the *Isocardia*-clay where it occurred in four samples (23 specimens in sample nr. 1113, and 14 in nr. 1109). It was also present in two samples of *Mytilus*-clay, and in one of *Cardium*-clay. — Its main recent distribution seems to be the boreal parts of the North Atlantic (NÖRVANG, 1945, p. 29).

Nonion pompilioides (FICHTEL and MOLL, 1798).

Plate II, figs. 7a-c.

Nautilus pompilioides FICHTEL and MOLL, 1798, p. 31, pl. 2, figs. a-c.
Nonionina umbilicatula, H. B. BRADY, 1884, p. 726, pl. 109, figs. 8a, b.
GÖES, 1892, p. 103, pl. 17, figs. 123a, b.

Nonion pompilioides, CUSHMAN, 1930, p. 4, pl. 1, figs. 7, 9, 10.
CUSHMAN, 1939, p. 19, pl. 5, figs. 9, 10.
HESSLAND, 1943, pl. 3, figs. 38a, b.

Description: Test planispiral, bilaterally symmetrical, involute, umbilici deeply excavated, peripheral edge broadly rounded especially towards the later chambers, peripheral outline circular, often somewhat irregular, not lobate; chambers about 12 in the last formed whorl, uniform, increasing slowly in size as added, usually not inflated; sutures limbate, generally flush with the surface, sometimes slightly raised, sometimes slightly deperessed, fusing along the umbilicus to form a slightly thickened, but not raised, ring; wall coarsely perforate; aperture a curved slit at the base of the low apertural face; colour white or somewhat translucent. Diameter 0,60 mm; thickness, 0,33 mm. The diameter usually varying about 0,5 mm.

Occurrence: This species is characteristic of the *Isocardia*-clay in the Oslofjord area. Due to their size they are rather conspicuous in the faunas.

Remarks: The specimens from the *Isocardia*-clay of the Oslofjord area are in very good accordance with the specimen from off Ireland figured by CUSHMAN (1930, pl. 1, fig. 10), and also with the specimen from Post-Glacial clay from Lunneviken, Bohüslän, Sweden, figured by HESSLAND (1943, pl. 3, figs. 38a, b). These figures are in good keeping with the original illustration of the species by FICHTEL and MOLL (1798, pl. 2, figs. a-c) copied by CUSHMAN, 1930, pl. 1, figs. 7a, b, and 1939, pl. 5, figs. 9a, b). BRADY's figures of *Nonionina pompilioides* (1884, pl. 109, figs. 10a, b and 11) do not fit this species, and neither do CUSHMAN's figures 11a, b (1930, pl. 1) and 11 and 12 (1939, pl. 5). These figures seem to be of a distinctly different species, being much broader and having less chambers in the youngest whorl than *Nonion popilioides*. It also seems to live under more severe environmental conditions than does *N. pompilioides*. *N. pompilioides* has a low-boreal-lusitanian distribution in the Atlantic. It occurs in the recent fauna of the Oslofjord.

Nonion germanicum (EHRENBERG, 1839).

Nonionina germanica EHRENBERG, 1839, p. 133, pl. 2, figs. 1a-g.

Nonion germanicum, Cushman, 1930, p. 8, pl. 3, figs. 4, 5.
Cushman, 1939, p. 22, pl. 5, figs. 31, 32.
Hessland, 1943, pl. 3, figs. 39a, b.

Two specimens from *Cardium*-clay from Oslo.

Nonion labradoricum (Dawson, 1860).

Plate II, figs. 8a-c.

Nonionina labradorica Dawson, 1860, p. 191, fig, 4.
Nonion labradorica, Cushman, 1927, p. 148, pl. 2, figs. 7, 8.
Cushman, 1939, p. 23, pl. 6, figs. 13—16.

Description (mainly after Cushman, 1939, p. 23): Test quite large, planispiral, involute, bilaterally symmetrical, peripheral edge bluntly angled, apertural face broadly triangular, the sides convex; chambers about 10, rapidly increasing in size as added; sutures distinct, curved, slightly depressed; wall thin, finely perforate; aperture a narrow slit at the base of the high apertural face. — The larger diameter of specimens from *Yoldia*-clay varied from 0,50 — to 0,80 mm, the minor diameter from 0,40 to 0,58 mm, and the breadth from 0,36 to 0,48 mm.

Occurrence: This species occurred frequently in samples of *Yoldia*-clay, being one of the characteristic species. It was present only in one sample of *Arca*-clay. It had a more or less intermittant occurrence in sediments of Post-Glacial age.

Remarks: In the *Isocardia*-clay the specimens of *Nonion labradoricum* had a form differing somewhat from the typical one, their marginal outline being slightly angular. This form was recognised also by Hessland (1943, p. 131) in a sample from Otterö (locality nr. 123, North Bohuslän). He found that it had much in common with Dawson's specimen from Gaspé Bay, reproduced by Cushman (1939, pl. 6, figs. 14a, b).

N. labradoricum is not a decidedly Arctic species. It is mainly distributed in the Arctic parts of the Atlantic, but it occurs also in the boreal ones (Nörvang, 1945, p. 28).

Astrononion gallowayi Loeblich and Tappan, 1953.

Astrononion stellatum Cushman and Edwards, 1937, p. 32, pl. 3, figs. 9—11.
Astrononion gallowayi Loeblich and Tappan, 1953, p. 90, pl. 17, figs. 4—7.

Occurred in all samples of *Yoldia*-clay but one, 24 to 2 specimens in each one. One specimen was present in a sample of *Arca*-clay (nr. 1116), one in a sample of *Mytilus*-clay (nr. 1118), and one in a sample of *Isocardia*-clay (nr. 1117). — Its main recent distribution is Arctic with intermittant occurrence in boreal waters.

This species has probably often been recorded as *Nonionina stelligera*.

Elphidium asterizans (FICHTEL and MOLL, 1798).

Nautilus asterizans FICHTEL and MOLL, 1798, p. 37, pl. 3, figs. e-h.
Nonionina asterizans, HERON-ALLEN and EARLAND, 1913.
Nonion asterizans, CUSHMAN, 1930, p. 6, pl. 2, figs. 5—7.
  CUSHMAN, 1939, p. 20, pl. 5, figs. 14—17.

This species occurred frequently in *Mytilus*-clay. The specimens from Vettakollen (sample nr. 1032) are closely related to the specimen figured by HERON-ALLEN and EARLAND (1913, pl. 13, figs. 12, 13).

Elphidium depressulum (WALKER and JACOB, 1798).

Nautilus depressulus WALKER and JACOB, 1798, p. 641, pl. 14, fig. 33.
Nonion depressulum, CUSHMAN, 1930, p. 3, pl. 1, figs. 3—6.
  BARTENSTEIN, 1938, p. 390, figs. 1a, b.
  CUSHMAN, 1939, p. 20, pl. 5, figs. 22—25.
  MACFADYEN, 1940, p. 281, text-fig. 2.
Elphidium depressulum, HESSLAND, 1943, p. 262.
Nonion depressulus, VOORTHUYSEN, 1950a, p. 41, pl. 3, figs. 4a, b.

This species was rare, it had an intermittent occurrence in clays of Post-Glacial age.

Elphidium orbiculare (H. B. BRADY, 1881).

Nonionina orbicularis H. B. BRADY, 1881, p. 105, pl. 2, figs. 5a, b.
Nonion orbiculare, CUSHMAN, 1930, p. 12, pl. 5, figs. 1—3.
  CUSHMAN, 1939, p. 23, pl. 6, figs. 17—19.
  MACFADYEN, 1940, p. 281, text-fig. 2.
Elphidium orbiculare, HESSLAND, 1943, p. 262.

Some specimens in a sample of *Mytilus*-clay from Vettakollen, and a few in *Ostrea*-clay from Sarpsborg.

Elphidium incertum incertum (WILLIAMSON, 1858).

Plate II, fig. 10.

Polystomella umbilicatula var. *incerta* WILLIAMSON, 1858, p. 44, pl. 3, figs. 82, 82a.
Polystomella striatopunctata, H. B. BRADY, 1884, pl. 109, fig. 23.
Elphidium incertum, CUSHMAN, 1930, p. 18, pl. 7, figs. 4—9.
Elphidium angulatum, THALMANN, 1932, p. 311 (Tafel 109, fig. 23).
Elphidium incertum, CUSHMAN, 1939, p. 57, pl. 15, figs. 21—24.
Elphidium incertum incertum, BRAND, 1941, p. 58.

Description: Test planispiral, bilaterally symmetrical, involute, moderately compressed, periphery broadly rounded, umbilical regions slightly depressed, often with a slight knob or, more often, irregularly arranged slits at the base of the sutures; chambers usually less than 10 in the last formed whorl, the later ones slightly inflated; sutures distinct, marked by the openings, retral prossesses few, 5—7, broad, strongly developed, especially by the later chambers; wall thick, usually opaque; aperture composed of several small, rounded openings at the base of the apertural face. Diameter about 0,3 mm.

Occurrence: This species was common in the *Isocardia*-clay, and occurred quite frequently also in other Post-Glacial sediments. It was rare in samples of Late-Glacial age.

Remarks: CUSHMAN (1939, p. 57) says that this is a coldwater species occurring in fairly deep water along the Continental Shelf from Cape Hatteras northwards to Cape Cod. In shallower water it has been found at Iceland and along the Norwegian coast as far north as North Cape. It was originally recorded from the British Isles. It has been recorded also from Alaska. Its main distribution thus seems to be boreal (cf. NÖRVANG, 1945, p. 31).

Elphidium incertum clavatum CUSHMAN, 1930.

Plate II, figs. 11a, b.

Elphidium incertum (WILLIAMSON) var. *clavatum* CUSHMAN, 1930, p. 20, pl. 7, figs. 10a, b.
CUSHMAN, 1939, p. 57, pl. 16, figs. 1, 2.
Elphidium incertum clavatum, BRAND, 1941, p. 58.
Elphidium incertum (WILLIAMSON) var. *clacatum*, VOORTHUYSEN, 1949a, p. 65, pl. 1, figs. 4b, c.
VOORTHUYSEN, 1950a, p. 42, pl. 4, figs. 1a, b; text-figs. 8a, b.

The subspecies differs from the typical form in being smaller and more compressed, the umbilical portions being occupied by one or sometimes more irregular bosses of clear shell material; chambers 8—12 in the last formed whorl, the later ones slightly inflated; sutures distinct, depressed, openings small, retral prosesses narrow but numerous; wall thin, smooth translucent, very often yellowish brown.

Occurrence: This species was very abundant in the Late-Glacial sediments, especially in the *Yoldia*-clay. It occurred in most of the treated samples, but in general sparingly in the Post-Glacial ones.

Remarks: Its main recent distribution is Arctic and boreal. I have taken it in great numbers in shallow water both at Spitsbergen and at Northeast Greenland (cf. ELLINGER, 1914; JØRGENSEN, 1944).

Elphidium incertum selseyensis (HERON-ALLEN and EARLAND, 1909).
Plate II, figs. 12a, b.

Polystomella striatopunctata (FICHTEL and MOLL) var. HERON-ALLEN and EARLAND, 1909, p. 695, pl. 21, figs. 2a-c.
Polystomella striatopunctata var. *selseyensis* HERON-ALLEN and EARLAND, 1915, p. 733.
Elphidium selseyensis, CUSHMAN, 1939, p. 59, pl. 16, figs. 26—28.
Elphidium incertum selseyensis, BRAND, 1941, p. 65.

Description: Test small, with inflated chambers, depressed sutures, and very short retral prosesses; the umbilical regions more or less filled with a vesicular mass, this filling extending along the sutures, thus partly obliterating the retral prosesses; wall thin, translucent.

Occurrence: The species occurred in most samples, rarely in the Late-Glacial ones, quite frequently in the Post-Glacial ones. — Its main recent distribution is probably boreal and lusitanian.

Elphidium excavatum (TERQUEM, 1875).

Polystomella excavata TERQUEM, 1875, p. 25, pl. 2, figs. 2a-f.
Elphidium excavatum, CUSHMAN, 1930, p. 21, pl. 8, figs. 1—7.
CUSHMAN, 1939, p. 58, pl. 16, figs. 7—12.
HESSLAND, 1943, pl. 3, figs. 41a, b.
VOORTHUYSEN, 1950a, p. 42, pl. 3. figs. 10a, b.

Rare, a few specimens in *Mytilus*- and *Cyprina*-clay and in *Isocardia*-clay. Its main recent distribution is probably lusitanian.

Elphidiella arctica (Parker and Jones, 1864).

Plate II, fig. 13.

Polystomella arctica Parker and Jones, 1864, p. 471, pl. 48, fig. 18.
Elphidium arcticum, Cushman, 1930, p. 27, pl. 11, figs. 1—6.
Elphidiella arctica, Cushman, 1939, p. 65, pl. 18, figs. 11—14
Voorthuysen, 1949b, pp. 127—129.
Voorthuysen, 1950a, p. 44, text-figs. 10, 11, 12.

Description: Test quite large, compressed; chambers about 10 in the last formed whorl, later ones very slightly inflated; sutures slightly depressed, two rows of openings with a thickened area between, no distinct retral prosesses but the openings often slit-like developed; wall thick, opaque, somewhat glistening; colour white.

Occurrence: This species occurred only in two samples of *Mytilus*-clay, one from Halden and one from Holmenkollen, Oslo, a few specimens in each one.

Streblus beccarii (Linnaeus, 1767).

Plate II, figs. 14a, b, 15a, b.

Nautilus beccarii Linnaeus, 1767, p. 1162.
Streblus beccarii, Fisher, 1817.
Rotalia beccarii, D'Orbigny, 1826, p. 275.
Cushman, 1931, p. 58, pl. 12, figs. 1—7; pl. 13, figs. 1, 2.
Streblus beccarii, Macfadyen, 1940, p. 281.

This species occurred quite frequently in *Ostrea*-clay and was also present in *Isocardia*-clay. It has long been recognised as an index fossil for Post-Glacial sediments in Scandinavia (M. Sars, 1865, p. 91; Munthe, 1894, p. 36).

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PLATES I—II

PLATE I

Fig. 1. *Rheophax subfusiformis* Earland. x 44. *Isocardia*-clay, Årum (nr. 1025a).
Fig. 2. *Quinqueloculina stalkeri* Loeblich and Tappan. a, b, x 72, different sides. *Arca*-clay, Konowsgt. 66, Oslo (nr. 1124b).
Fig. 3. *Quinqueloculina seminulum* (Linnaeus). a, b, x 35, different specimens. *Isocardia*-clay, Svenengen, Oslo (nr. 1100a).
Fig. 4. *Triloculina trihedra* Loeblich and Tappan. x 44. *Isocardia*-clay, Svenengen, Oslo (nr. 1100b).
Fig. 5. *Pyrgo* sp. x 44, a, side view, b, front view. *Yoldia*-clay, Jomfruland (nr. 1017a).
Fig. 6. *Pyrgo* sp. x 44. *Isocardia*-clay, Monradsgate, Oslo (nr. 1028a).
Fig. 7. *Ophthalmidium inconstans* (H. B. Brady). x 65, a, b, different specimens. *Isocardia*-clay, Valle, Sarpsborg (nr. 1113a).
Fig. 8. *Lagena elongata elongata* (Ehrenberg). x 85. *Arca*-clay, Tuengen, Oslo (nr. 1023a).
Fig. 9. *Lagena elongata distoma* Parker and Jones. x 85. *Arca*-clay, Tuengen, Oslo (nr. 1023b).
Fig. 10. *Bulimina marginata* D'Orbigny. x 45, a, b, different specimens. *Isocardia*-clay, Monradsgate, Oslo (nr. 1028b).
Fig. 11. *Globobulimina turgida* (Bailey). x 48. *Isocardia*-clay, Borregård, Sarpsborg (nr. 1109a).
Fig. 12. *Virgulina* cf. *davisi* Chapman and Parr. x 85, a, b, apertural view of different specimens. *Arca*-clay, Tuengen, Oslo (nr. 1023c).
Fig. 13. *Virgulina fusiformis* (Williamson). Different specimens; a, b, x 44; c. x 74. *Cardium*-clay, Frogner, Oslo (nr. 1108a).
Fig. 14. *Uvigerina peregrina* Cushman. x 45. *Isocardia*-clay, Porsnes, Halden (nr. 1117a).

PLATE 1

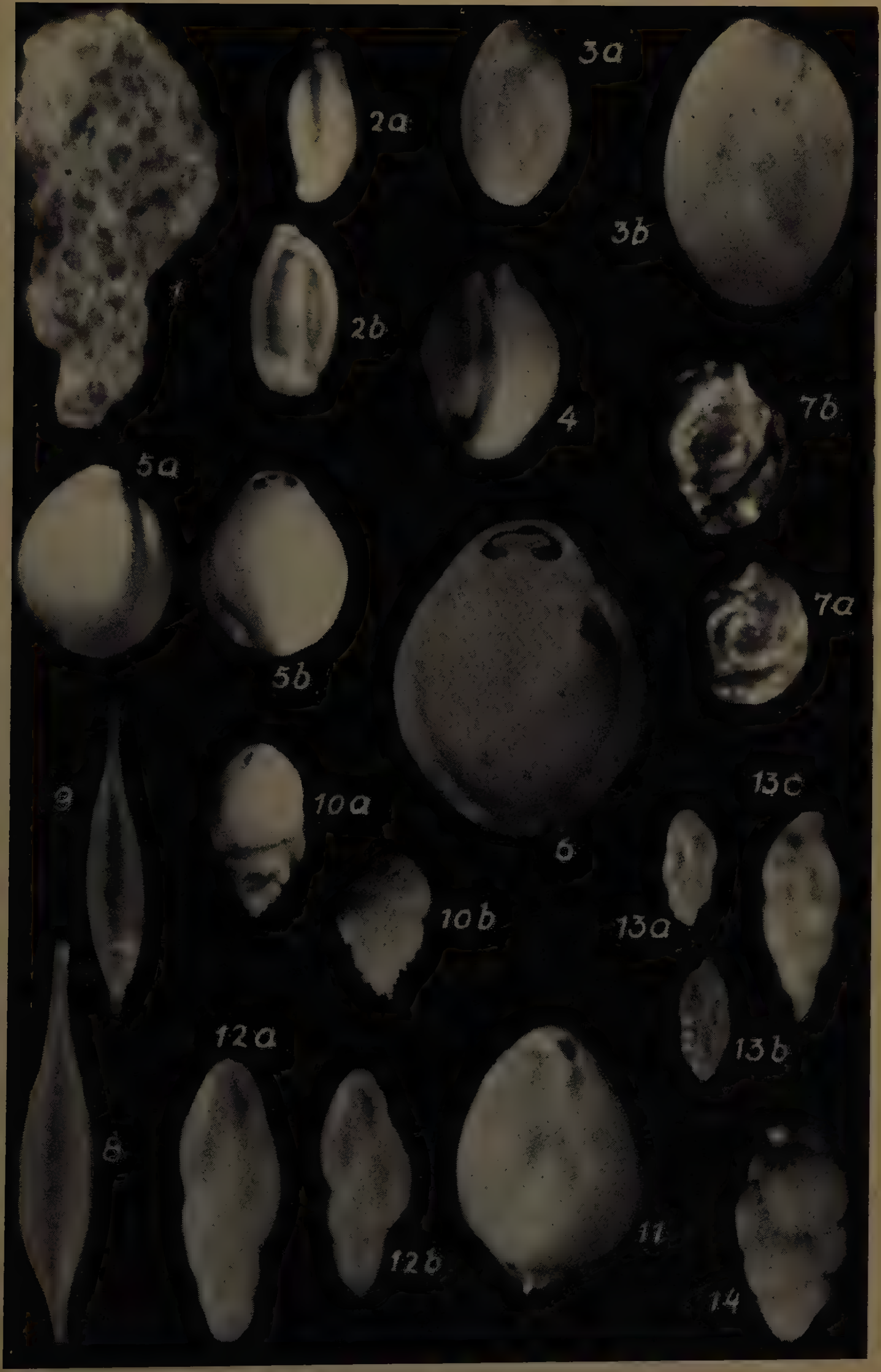


PLATE 2

Fig. 1. *Cassidulina crassa* D'Orbigny, x 55; a, ventral view, b, dorsal view, different specimens. *Yoldia*-clay, Jomfruland (spl. nr. 1017b).

Fig. 2. *Cassidulina laevigata* D'Orbigny. x 44; a, dorsal view, b, ventral view, different specimens. *Yoldia*-clay, Jomfruland (spl. nr. 1017c).

Fig. 3. *Pullenia quinqueloba minuta* subsp.n. x 74; a, side view, b, apertural view. Holotype. *Arca*-clay, Konwsgate 66, Oslo (Fo. nr. 1124a).

Fig. 4. *Eponides exiguus* (H. B. Brady). x 68; a, ventral view, b, dorsal view. *Isocardia*-clay, Svenengen, Oslo (spl. nr. 1100c).

Fig. 5. *Cibicides lobatulus* (Walker and Jacob). x 31; a, ventral view, b, dorsal view, different specimens. *Yoldia*-clay, Jomfruland. (spl. nr. 1017d).

Fig. 6. *Nonionella turgida* (Williamson). x 71; side view. *Isocardia*-clay, Borregård, Sarpsborg (nr. 1109b).

Fig. 7. *Nonion pompilioides* (Fichtel and Moll). x 44; a, side view of a specimen from *Isocardia*-clay from Årum, Sarpsborg (spl. nr. 1025b); b. apertural view c, side view of different specimens from *Isocardia* clay, Borregård, Sarpsborg (spl. nr. 1109c).

Fig. 8. *Nonion labradoricum* (Dawson). x 42; a, side view, b, c, oblique view partly showing the aperture; different specimens. *Yoldia*-clay, Jomfruland (spl. nr. 1017e).

Fig. 9. *Astrononion gallowayi* Loeblich and Tappan. x 44. *Yoldia*-clay, Jomfruland (spl. nr. 1017f).

Fig. 10. *Elphidium incertum incertum* (Williamson). x 40. *Isocardia*-clay, Årum, Sarpsborg (spl. nr. 1025c).

Fig. 11. *Elphidium incertum clavatum* Cushman. x 40; a, b, different specimens from *Yoldia*-clay, Valle, Sarpsborg (spl. nr. 1020a).

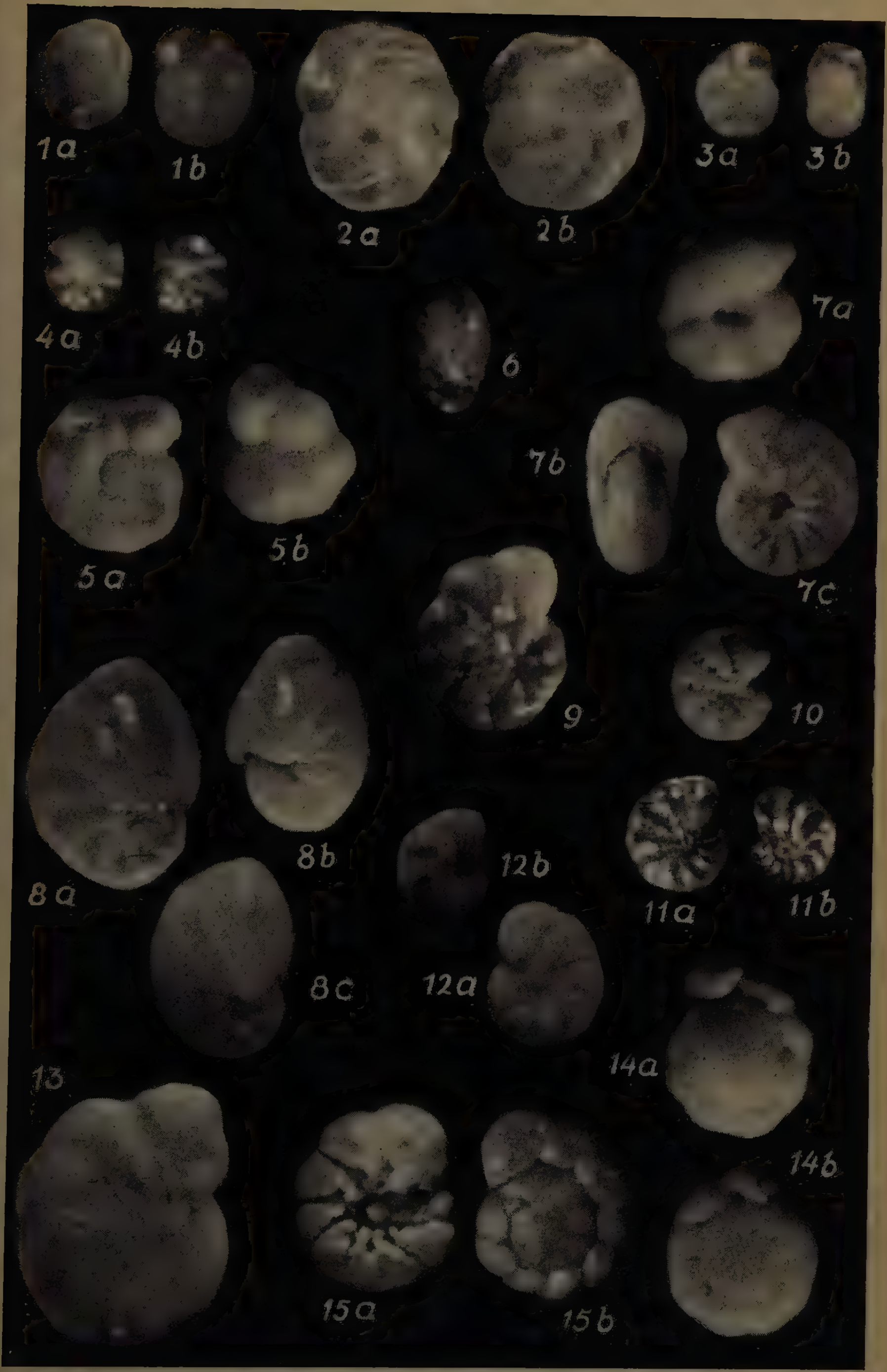
Fig. 12. *Elphidium incertum selseyensis* (Heron-Allen and Earland). x 45; a, b, different specimens from *Isocardia*-clay, Årum, Sarpsborg (spl. nr. 1025d).

Fig. 13. *Elphidiella arctica* (Parker and Jones). x 45. *Mytilus*-clay, Lund, Idd by Halden (spl. nr. 1118a).

Fig. 14. *Streblus beccarii* (Linnaeus). x 55; a, b, dorsal side of two specimens from *Isocardia*-clay, Årum, Sarpsborg (spl. nr. 1025e).

Fig. 15. *Streblus beccarii* (Linnaeus). x 44; a, ventral side, b. dorsal side of a specimen from *Ostrea*-clay, Borregård, Sarpsborg (spl. nr. 1114a).

PLATE 2


1a
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15a
15b

SOME OBSERVATIONS ON THE REGIONAL DISTRIBUTION OF LEAD IN SOUTH NORWEGIAN GRANITIC ROCKS

BY

IVAR OFTEDAL.

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Abstract. From results based on relatively few spectrochemical analyses of alkali felspars it is concluded that certain regions in Southern Norway are fairly rich in Pb, others — in particular the Oslo Region — very much poorer. The more or less tentative conclusions are discussed.

Introduction.

The data presented below have been obtained by spectrochemical analysis. It is obvious that a true picture of the distribution of an element over large areas could be obtained only through examination of very large numbers of suitably selected specimens. For instance, it can by no means be presumed that the alkali felspars of a single granite body, or from a single pegmatite locality, will show constant percentages of minor elements. Therefore each granitic body, large or small, within the examined area, should be represented by numerous samples. The material so far examined is very far from satisfying such a requirement, in fact it consists of scattered samples from selected districts within the southernmost part of Norway. Nevertheless the results obtained from this very limited material seem to reveal facts of some geological interest. I hope to be able to collect much more data, but this can hardly be done in the near future, since at present I have no opportunity of securing the necessary number of spectrograms within a reasonable length of time. Therefore the publication of the following preliminary results may be justified.

Material and analytical procedure.

Only alkali felspars were examined, as these contain nearly all the Pb present in granitic rocks. (Some samples of plagioclase felspars from granites only confirmed this fact). The felspars were taken from massive granites, from pegmatitic veinlets in gneiss, and from larger granite pegmatite bodies. A few samples from other rock types were also examined.

All the spectrograms were taken by the carbon arc method, the powdered sample being packed into a cavity in the cathode. Dimensions of cathode: outside diameter 3 mm, diameter of cylindrical cavity 1.5 mm, depth of cavity 4 mm. The cavity was filled completely with the pure powdered sample. The exposure was interrupted after 1½ to 2 minutes, as it was found that longer exposures did not bring out any more of the trace element in question. The purpose of the spectrochemical work was to estimate approximately the contents of Pb in the various felspar samples, and in particular to record appreciable variations in the Pb concentrations.

About one half of the spectrograms were taken some years ago by myself with a large glass spectrograph belonging to Statens råstofflaboratorium (the State Raw Material Laboratory), then at the Geologisk museum, Oslo. The arcing was done at 120 V and 5 to 6 A, and the image of the cathode layer was focussed on the slit. In the spectral region used the only sentisive Pb line was 4057.82. The intensities of this line were estimated visually. All the spectrograms were of a very uniform good quality. Of course no estimates of the absolute Pb concentrations were obtained in this way. However, it was brought out very clearly that the examined felspars exhibit a wide range of Pb concentrations. The work was interrupted at this stage, as the Råstofflaboratorium moved from Oslo to Trondheim.

The other half of the spectrograms were taken recently by Mr. RUTLIN, civil engineer, with a Large Hilger Quartz Spectrograph belonging to Sentralinstituttet for industriell forskning (Central Institute for Industrial Research) at Blindern, Oslo. The loading of the cathode carbons was done in the Mineralogisk institutt. The arcing conditions differ somewhat from those mentioned above, in particular the voltage was considerably higher (230 V). In all cases, apart from some trial exposures, the arc image was formed on the prism, and a rotating stepped sector employed. The spectrograms obtained in this way were naturally somewhat less intense than the above ones. On the other hand they permit more accurate estimates of the intensities. No use was made of a photometer. For the present purpose a simple inspection of the stepped lines is found to give the intensities with sufficient precision, provided the strong K lines look equally intense in all spectrograms. Actually it is this rapid way of approximate intensity estimation that makes it possible to survey a large material in a comparatively short time. The spectral region chosen contained all the 3 sensitive Pb lines 4057.82, 3683.47, 2833.07. The intensities of the Pb lines in the felspar spectrograms were compared with the corresponding ones in standard mixture spectrograms. The standard mixtures were prepared as follows. A pegmatite microcline perthite which had been found to contain practically no Pb was made the base substance. This was mixed with glass containing 30 % PbO, kindly supplied by Hadelands Glassverk. The mixtures were made to contain 0.3 %, 0.1 %, 0.03 %, 0.01 %, 0.003 %, 0.001 % PbO. (They also contained the same percentages of Tl_2O, added as Tl_2SO_4). The mixtures were prepared by the assistant of the Mineralogisk institutt, cand. mag. THOR SIGGERUD. By means of the standard mixture spectrograms the percentages of Pb (and Tl) in the felspar samples could be given approximately. Spectrograms of some of the felspars examined in this way had been taken previously with the glass spectrograph as described above. In these cases a relationship between the intensities of the Pb lines and the corresponding Pb percentages could be established also for the older series of spectrograms, which could hence be interpreted in terms of Pb percentages, although with less accuracy than the newer series.

Results of spectrochemical analysis.

The estimated Pb concentrations are given in the table. The data has been arranged according to geological regions. Data from the older and newer series of spectrograms have not been particularly marked. The actual figures given should not be taken too literally, but they certainly give the right order of magnitude of the percentages. Pb lines are visible at concentrations considerably below 0.001% especially in spectrograms of the older series.

Pb concentrations in alkali felspar.

Parts per million. — 0: Pb lines not recorded.

Rock and locality.	Pb
Østfold-Akershus gneiss area.	
Pegmatitic veinlets or augen in gneiss.	
4 samples (Enebakk; Klemetsrud (2); Simensbråten), each	20
1 sample (Susebakke, Mysen)	0
Larger pegmatite bodies.	
3 samples (Spydeberg; Oksøy, Vannsjø (2)), each	50
Østfold granite.	
Iddefjord, typical specimen	20
Fredrikstad, porphyric, with gneiss xenoliths	<10
Kjølberg, Onsøy, reddish	50
Oslo Region.	
Granite. 3 samples (Drammen; Heggedal; Bjørgeseter), each	0
Ekerite. 1 sample (Hamre, Eiker)	0
Nordmarkite. 2 samples (Grorud; Sognsvann), each	0
Larvikite. 2 samples (Tjølling; pegmatite, Stavern), each	0
Lardalite. 1 sample (Løvemoen, Lågendalen)	0
Pegmatite. Langesundsfjord (Barkevikskjær)	0

Kongsberg-Bamble Formation in the Sørland area.

Granite pegmatite.

Bamble-Kragerø district.

14 samples (Trossby; Hasalvik; Isnes; Kjørstad; Lille Furuholmen; Store Furuholmen; Fluer; Kirkeholmen; Malmtangen; Midt Gumøy; Kalstad; Sjåen; Stene (2)), each	0
2 samples (Feset; Lindvikskollen) each	<10

Risør-Arendal district.

4 samples (Mørefjær; Røyerfjell; Klodeberg; Gloserhei), each	0
9 samples (Lekerøy; Ramskjær; Båseland; Vasstølen; Sandøy (2); Borøy; Mørefjær; Øyestad), each	<10
2 samples (Ramskjær; Våje), each	10
2 samples (Rullandsdalen; Mørefjær), each	20
1 sample (Torbjørnsbu)	30
1 sample (Landbø, Ø. Moland)	50

Grimstad-Lillesand district.

1 sample (near Grimstad, in gneiss)	<10
1 sample (Tangvik, Justøy, in plagioclase gneiss)	10
3 samples (—"—), each	0

Large granite bodies.

Vegårshei granite. 1 sample (Espelandsmyr st.)	10
Grimstad granite. 1 sample (Ryvingen)	20
2 samples (Valøya; Grefstadvik), each	10
Birkeland granite. 1 sample (Grøsle)	<10

Telemark granite region.

Telemark granite.

1 sample (Bø st., pegmatitic, in gneiss granite)	<10
1 sample (Bjorvann, Tørdal; massive, grey)	20
3 samples (Knaben II; somewhat gneissic), each	0
1 sample (Knaben II; pegmatitic)	10

Granite pegmatites in gneiss-gabbro areas.

Tørdal in Telemark. Amazonite pegmatites.

3 samples (Skarsfjell), each	1000
5 samples (Høydalen), each	500

Iveland-Evje.

1 sample (Landsverk)	0
2 samples (Eptevann; Kåbuland), each	<10
3 samples (Ertveit (2); Kåbuland), each	10
2 samples (Hiltveit; Kåbuland), each	30
3 samples (Rosås; Støledalen; Kåbuland), each	50
2 samples (Landås, microlite locality; Landsverk), each	100

Summarizing the data from the table one arrives at the following results, which — in view of the relative scarcity of the material — must be considered more or less tentative.

As the Pb concentration in alkali felspar obviously may vary widely even within quite small areas, it is clear that a few samples will not in general give the average value for a larger area. However, it is probable that the concentration will be fairly constant within a massive and uniform granite body, like most of the Østfold granite or the Grimstad granite. And in certain cases it appears that the average Pb concentration for larger areas may be estimated with some confidence.

I. *Østfold-Akershus Archaean area.* Nearly all the examined specimens are fairly rich in Pb. The average value for the area might be something like 20 to 30 p. p. m., which is about the general average for granitic rocks according to present views (1).

II. *Oslo Region.* The granites («Drammen granite» and ekerite), as well as other members of the Oslo igneous rock series, appear to be practically devoid of Pb. As all the spectrograms were taken by the highly sensitive cathode layer method the Pb contents can hardly exceed the order of 1 p. p. m.

III. *Kongsberg-Bamble Formation in the Sørland area.* (2) (3).

The large granite pegmatites in the eastern part (Bamble-Kragerø) are, apparently without exception, extremely poor in Pb. The average percentage of Pb in the alkali felspars is probably below 5 p. p. m.

In the Risør-Arendal district some pegmatites exhibit fairly high Pb concentrations, but the majority seem to be poor in Pb. The average value might be something like 10 p. p. m.

The few samples from pegmatites farther west again indicate very low Pb contents.

For the Vegårshei granite and the Grimstad and Birkeland granites Pb contents around 10 p. p. m. are indicated.

IV. *Telemark granite.* The few samples give very little information about the distribution of Pb in this vast region of granitic rocks. The rather high Pb concentration in the sample from Tørdal is probably characteristic of a certain massive type which covers a considerable area in this district and is — by the way — very similar to the grey Iddefjord granite in appearance.

V. *Granite pegmatites in gneiss-gabbro areas within the Telemark granite region.* The alkali felspars from these deposists are frequently relatively rich in Pb, and may be extremely so.

In the Iveland-Evje area (3) (4) (5) the observed Pb concentrations vary between 100 p. p. m. and less than 5 p. p. m. The average value might be 30 p. p. m. or more.

The Pb concentrations in the Tørdal amazonites, 500 to 1000 p. p. m., are quite exceptional (6).

Discussion of results.

Assuming the above results to be essentially correct the question arises, how they could be explained or understood.

There are considerable differences in the average Pb concentrations for different Archaean areas. But the most conspicuous feature is certainly the difference between the Oslo granites on the one hand and the Archaean granites on the other. Obviously the incorporation of Pb in alkali felspar is in some way connected with palingenic processes. Thus a notable replacement of K by Pb in felspar is certainly possible at fairly low temperatures of formation, temperatures within the stability field of microcline. The actual Pb content of a given microcline crystal must obviously depend on the occurrence of Pb in the country rock prior to granitization. It appears that nearly all the Pb present in the original country rock is incorporated in the microcline formed by the granitization process. Therefore the average Pb concentration in a granitized area can generally not be predicted, and in addition great local variations must be expected to occur. On the other hand, in extreme cases of granitization, where real palingenic magmas have formed, it is probable that the resulting massive granite bodies will exhibit fairly uniform Pb concentrations. If such a granite body is very large it has presumably been formed by granitization of a very large volume of country rock, which may have been composed of various rock types and deposits and approached more or less the average composition of the upper crust. Therefore it is probable that very large and uniform palingenic granite bodies will approach a definite Pb concentration, the general average value for granitic rocks. It is not possible to decide if any appreciable part of the Pb has been introduced by the granitizing agents themselves. Facts discussed below do not support such a view.

The virtual absence of Pb in the Oslo eruptive rocks, including the granites which ought to be the Pb-richest members, may have two reasons: 1. Practically no Pb was present in the magmas, and 2. At the fairly high temperature of formation the alkali felspar — orthoclase — was not able to incorporate appreciable quantities of Pb. — *Some* Pb was certainly present in the magmas, since a number of small galena deposits occur in the contact zones. However, as a rough calculation shows, if 10 g — or even 1 g — Pb had been expelled from every ton of the granite magma there would have been truly enormous lead enrichments in the environs of the large granite bodies. It is true that the greater part of these deposits might have been carried away by the subsequent erosion, but even so one would expect very large lead deposits to occur in the contact zones. Thus it may be concluded that the Oslo magmas were extremely poor in Pb. Conseqently the mere absence of Pb in the alkali felspars of the Oslo rocks will not prove that high temperature alkali felspar, orthoclase, is unable to incorporate Pb in its structure. On the other hand, the fact that lead deposits occur at all in the contact zones of the Drammen granite, in spite of the virtual absence of lead in the orthoclase of the granite, would seem to prove this adequately. The evidence strongly supports the view that, whereas microcline formed by granitisation processes is able to incorporate considerable quantites of Pb, orthoclase formed within a certain range of higher temperatures is practically unable to incorporate Pb. The relationship between the Drammen granite and the other Oslo rocks is not quite clear. The present observations may indicate that the granite is a true member of the series. This need not mean that it is a differentiation product of a common parental Oslo magma. Virtual absence of Pb may be a characteristic of very hot magmas. Then the observed facts would simply suggest that the granite and the other Oslo rocks had a deep-seated — not necessarily common — origin.

If this is generally true, the high Pb concentrations in some palingenic granites should be due almost entirely to consumption of rock complexes in the upper crust, where lead had been enriched through pneumatolytic and hydrothermal processes.

This view is supported also by the data obtained from granite pegmatites. A very large proportion of the examined pegmatites, especially in the Kongsberg-Bamble Formation, are extremely poor in Pb. Most geologists will probably agree that these pegmatites — small veins or larger bodies — represent incipient granitization processes or vestiges of granitization processes which have been going on at greater depth. Thus itappears that the granitization process itself does not introduce appreciable amounts of Pb into the rocks.

The Pb-rich pegmatites, especially in the Iveland-Evje and Tørdal areas, may have formed through granitization of rock complexes locally enriched in Pb, but in many cases it is more probable that they are connected with larger palingenic granite bodies in the «classical» way, and contain certain constituents in higher concentrations than the granite itself. Thus the Tørdal amazonites are not only extremely rich in Pb, they also contain similar percentages of Tl and are high in Rb and Cs; the pegmatites also carry lepidolite and cassiterite (6). The relatively Pb-rich veins and bodies of pegmatite in the Østfold-Akershus area may have a similar origin. They may very well to some extent be connected with the Østfold granite.

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Oslo, Mineralogisk institutt,
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ECLOGITE-AMPHIBOLITE ON THE MOLDE PENINSULA, SOUTHERN NORWAY

BY

IVAR HERNES

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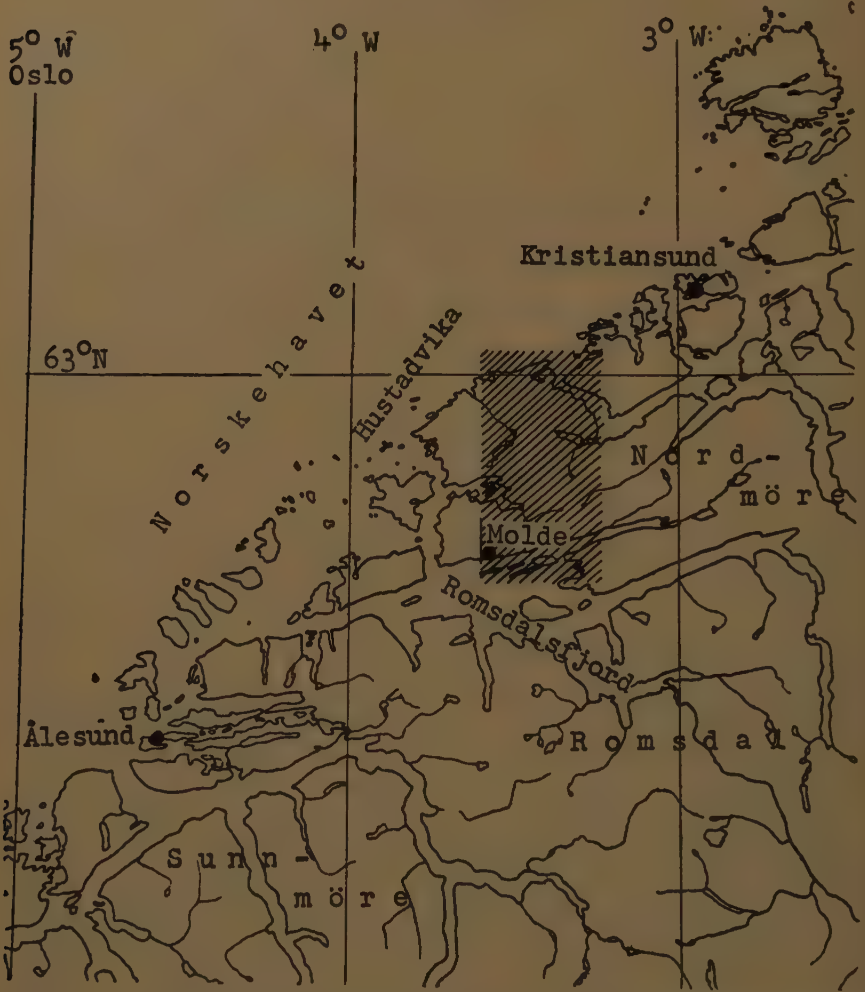

Fig. 1. The hatched square shows the position of the geological map, fig. 2.

Abstract. The Molde peninsula, on the north-western coast of Southern Norway, consists mainly of quartzdioritic, granodioritic, and granitic gneisses. Numerous lenses in the gneiss and three larger zones in the central part of the peninsula are composed of dark, basic rocks, such as eclogite, eclogite-amphibolite, garnet amphibolite and amphibolite. Embedded in these three zones are several occurrences of calcite marble.

The mutual connection between the dark, basic rocks is examined, and it is proved that they have passed trough an increasing metamorphism up to eclogite facies, and then through a diaphtorism to epidote amphibolite facies. A complete equilibrium has not been attained at any stage and the different mineral associations represent relics. The rocks are called eclogite-amphibolite, after the most common mineral parageneses. The eclogite-hornblende gabbro is thought to represent a stage in this metamorphic series.

There follows a discussion of the genesis of the eclogite-amphibolite and of the age of the Molde peninsula.

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The paper has been written at the Geological Institute of the University of Bergen, and I am grateful to Professor NIELS-HENR. KOLDERUP for his interest.

Miss ELLEN IRGENS has drawn the map and made the photomicrographs, and Preparant A. IVERSEN has made the thin and polished sections. For this help also I would like to express my gratitude.

Geological Institute, University of Bergen,
March, 1953.

PETROLOGICAL SURVEY OF THE MOLDE PENINSULA.

Introduction.

The Molde peninsula is situated on the north-western coast of Southern Norway, between Romdalsfjord and Hustadvika. It is a mountainous area, with summits of up to 1000 meters above sea-level. Towards the Norwegian Sea the *strandflat* is well developed. Owing to its exposed position the peninsula has a harsh climate, and only in the southern part, towards Romsdalsfjord, with the town of Molde and the famous Fannestrand, is it more temperate.

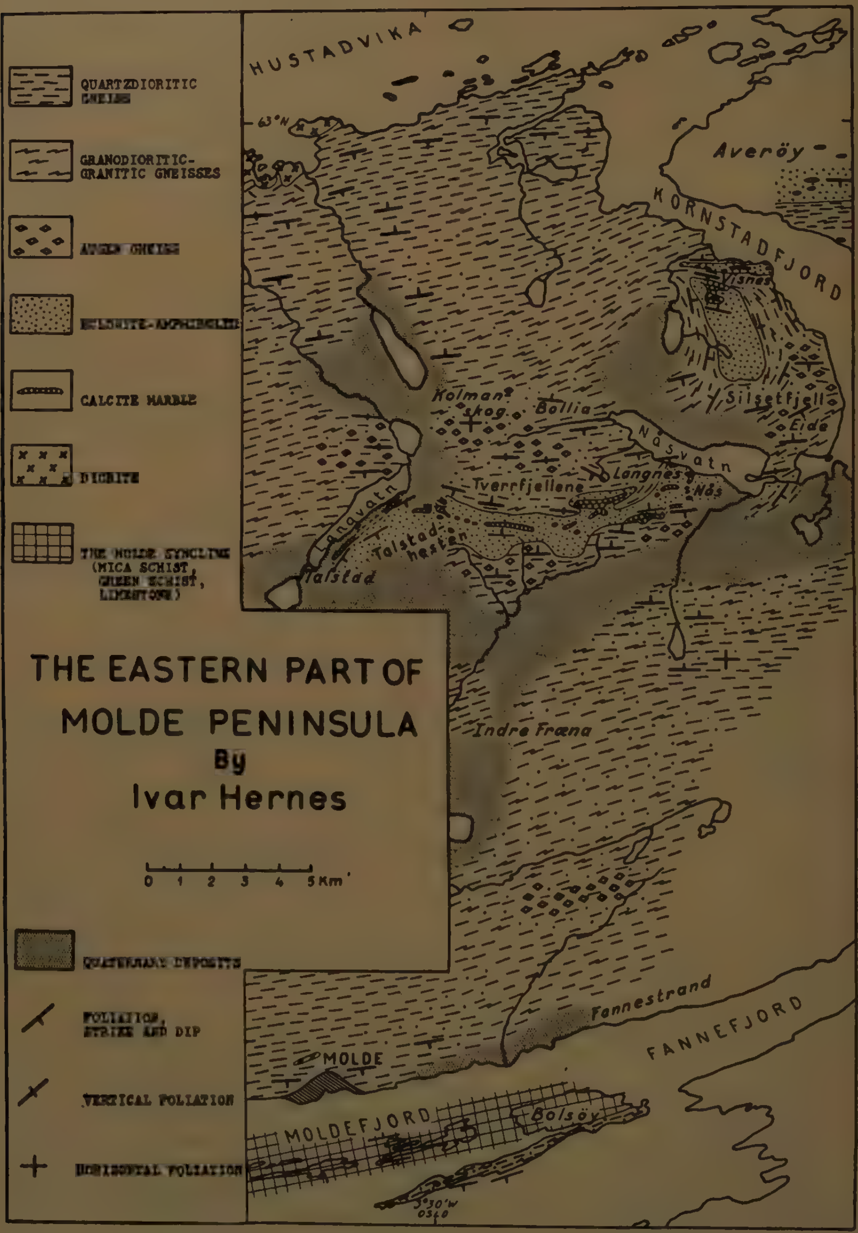

Fig. 2. Geological map of the eastern part of the Molde peninsula.

The Molde peninsula forms a part of the North-Western Gneiss Area of Southern Norway. It extends along the west and north-west coast, from about 60° lat. N. to 65° lat. N. In the south-east and east the Gneiss Area is bounded by Eo-Cambrian and Cambro-Silurian sedimentary rocks, which were metamorphosed during the Caledonian orogeny. Within the Gneiss Area there are synclines of metamorphosed Cambro-Silurian sediments, and late to post-orogenic sediments of Downtonian and Devonian age. The Gneiss Area was formerly regarded as being mainly Archean, but is now believed to be mainly Caledonian.

Previous Investigations.

The county of Møre and Romsdal, which forms a central part of the North-Western Gneiss Area consists, from south to north, of Sunnmøre, Romsdal, and Nordmøre. Of Sunnmøre there is a general geological map by REUSCH (1877), and a new one by GJELSVIK and GLEDITSCH (GJELSVIK 1950). Of Romsdal and Nordmøre there is no corresponding map.

The Molde peninsula is situated on each side of the border between Romsdal and Nordmøre. KJERULF (1879) has made a section which cuts the peninsula from north to south. J. H. L. VOGT (1897) and C. BUGGE (1905) give an outline of the marble deposits, ESKOLA (1921) mentions a deposit of eclogite-hornblende gabbro, and FOSLIE (1925) mentions in his register two deposits of ore on the peninsula.

The Molde islands, south of the peninsula, have been described by C. BUGGE (1934).

The Gneiss.

The Molde peninsula is composed chiefly of gneisses. The direction of the strike is approximately east — north-east, and this direction predominates in the topography. The most marked valley direction follows the direction of the strike, and both Moldefjord and Fannefjord, as well as the coastline at Hustadvika, are determined by it.

In the northern and southern districts of the peninsula the gneiss is a quartzdioritic homogeneous grey biotite gneiss, in which the biotite content varies somewhat. Dark bands, rich in biotite, occur but are not distinctly separated from the usual, lighter type of gneiss. Dark basic lenses, with a sharp boundary to the surrounding gneiss, occur in small amounts. In addition, there are veins and schlieren of granitic pegmatites. The gneiss has a distinct foliation, and in these homogeneous zones the direction of the strike and the dip is very regular. The districts of Molde and Hustadvika consist mainly of this homogeneous gneiss.

In the central districts of the peninsula the gneiss is more heterogeneous, varying in composition from quartzdioritic through granodioritic to granitic. This heterogeneous gneiss varies from grey to red. It is chiefly a biotite gneiss, but amphibole gneiss does also occur. The gneiss is in parts developed as augen-gneiss, with red augen rich in microcline. In size these augen vary from several decimeters down to the barely visible.

The appearance of the augen-gneiss is sometimes reminiscent of a red granite. In some areas there are numerous dark, basic inclusions. In addition there are numerous veins and schlieren of granitic pegmatites. The direction of the strike and the dip is irregular. The districts at Eide and at Kolmanskog consist of heterogeneous gneisses, but considerable amounts of augen-gneiss are also found here.

Several phenomena go to indicate that the plagioclase gneiss is of sedimentary origin; it is distinctly foliated and shows banding. Together with the gneiss there are large deposits of crystalline limestone, typically sedimentogeneous in appearance. Dr. C. BUGGE has further found mica schists near Bud, in the north-western part of the Molde peninsula. STRAND (1949, p. 7) describes this occurrence as being «somewhat feldspatized rocks, clearly recognizable as wrinkled micaschists at that locality. The micaschists pass into the gneisses, and the same wrinkling and other folding patterns may also be observed in the gneisses.» It is therefore natural to suppose that the plagioclase gneiss has originated from argillaceous sediments, which, through the addition of sodium and lime, have been transformed into plagioclase gneiss.

A further transformation from the quartzdioritic composition into a granodioritic and granitic one, can be observed from field and microscopical studies. Both a potash and a silica metasomatism must have taken place, and have resulted in the formation of microcline porphyroblasts, in inclusions of quartz in the plagioclase, and also in the formation of free grains of quartz. These minerals appear to have been formed at the expense of the plagioclase, so that the amount of lime and sodium must have decreased. Further, the amount of the dark ferro-magnesian minerals has distinctly diminished, and the iron and magnesium content must have decreased correspondingly.

It is very likely that the material has migrated in the rocks, which were, during the process, in a non-magmatic state. In some places there is evidence of local movements having taken place after the granitization process. It is, however, evident from the field and microscopical investigations that no movements of any appreciable regional character can have taken place during or after the granitization process.

The Eclogite-Amphibolite.

As mentioned above, there are numerous occurrences of dark, basic lenses in the gneiss. The lenses vary from massive to slightly foliated, the foliation being most distinct at the gneiss contact and conformable to this. The content of minerals varies somewhat; rocks occurring include eclogite, eclogite-amphibolite, garnet amphibolite and amphibolite.

A zone with corresponding rocks has been followed along the mountains of Talstadhesten and Tverrfjellene, from Talstad in the west to Lake Nåsvatn in the east. The direction of the strike is here westerly. Another zone goes from the highest part of the mountain of Silsetfjell to Visnes, with the direction of the strike varying from north to west, while a third one, with westerly strike direction, is found at Visnes. All three zones form synclines, and have a sharp boundary to the surrounding gneiss. Veins of granitic pegmatite have penetrated both into the lenses and into the three zones, but they are far less frequent than in the surrounding gneisses.

The various rocks in these three zones and in some lenses are further examined, and their mutual connection is dealt with in the following discussion of the eclogite-amphibolite.

The Marble.

Several occurrences, both large and small, of marble are found on the Molde peninsula, the marble being more or less completely embedded in the three above-mentioned eclogite-amphibolite zones. The length of the marble deposits in the strike direction varies from only a few meters up to 3 kilometers. The deposits form distinct zones.

Most of the marble deposits are found in the eclogite-amphibolite zone along the mountains of Talstadhesten and Tverrfjellene One marble zone, bordering on Lake Langvatn, occurs at the foot of Talstadhesten, on its northern side. Another one is found higher up the mountain, and continues through the pass between Talstadhesten and Tverrfjellene. Further east a series of marble deposits occur in the higher parts of Tverrfjellene; on lower ground the deposits are found only at Nås and Langnes.

In the eclogite-amphibolite zone of the mountain of Silsetfjell a large marble deposit occurs in the north, at Visnes. In the eclogite-amphibolite zone at Visnes there are several smaller marble deposits.

The marble is a calcite one which ordinarily contains little in the way of silicate inclusions. The colour is usually white or bluish, but may, in some cases, be very beautiful, as, for example, a lemon-coloured variety seen at Nås. The coloured parts occur most frequently where the marble borders onto other types of rock.

At the contact marble/gneiss and marble/eclogite-amphibolite reaction skarns are developed. The dominant skarns are from the marble: scapolite skarn, pyroxene skarn and amphibole skarn.

A few granitic pegmatite veins are observed in the marble.

DISCUSSION OF THE ECLOGITE-AMPHIBOLITE

Mineralogy.

The chief minerals are plagioclase, monoclinic pyroxene, garnet and amphibole, the ratio between them varying considerably. The rocks consist mainly of plagioclase and pyroxene, of garnet and pyroxene, and of amphibole and plagioclase. We propose to show, in the chapter on metamorphism, that these mineral parageneses represent different metamorphic stages of the same rock.

The accessory minerals are epidote, zoisite, orthorhombic pyroxene, biotite, sericite, chlorite, quartz, scapolite, calcite, apatite, titanite, rutile, hematite, ilmenite, limonite and pyrrhotite.

Some data on minerals from different rock types and various localities are given in the following survey. Sample no. 1 is the least altered, and no. 5 the most altered type. As, however, the mineral content may vary very considerably in a series of thin sections from one specimen, it is very difficult to state any definite order. Sample no. 1 is taken from the Silsetfjell zone, just north of the summit of Silsetfjell. No. 2 is from a lens from the top of Stortuva, on the south-east side of Silsetfjell. No. 3 is from a lens on the southern bank of a small river which flows through the marshy district south of Bollia. Nos. 4 and 5 are from the Tverrfjellene zone — no. 4 being taken from the central part of this zone and no. 5 from Nås.

The error in the refraction determinations should be within $\pm$ 0.002—0.003 for N, Ng, and Np. Nm has not been determined with corresponding accuracy, but the error limit is assumed to be only slightly higher.

Plagioclase. As will be described in the chapter on metamorphism, two types of plagioclase occur.

A: Aggregates of small plagioclase crystals: $2V \approx 90°$.

No. 1: Ng = 1.554, Nm = 1.551, Np = 1.547, Ng $\div$ Np = 0.007.
No. 2: Ng = 1.556, Nm = 1.552, Np = 1.548, Ng $\div$ Np = 0.008.

These figures correspond to andesine with $An_{35}Ab_{65}$ and $An_{37}Ab_{63}$. By measuring the maximum extinction angles in zone $\perp$ 010, X' $\wedge$ 010, the plagioclase is determined as andesine containing An_{45}.

B: Plagioclase together with amphibole: $2V \approx 90°$.

No. 5: Ng = 1.546, Nm = 1.542,Np = 1.538, Ng $\div$ Np = 0.008.

These figures correspond to oligoclase with $An_{18}Ab_{82}$. By measuring the maximum extinction angles in zone $\perp$ 010, X' $\wedge$ 010, the plagioclase is determined as oligoclase containing An_{18}.

Monoclinic pyroxene. + 2V = ca. 65°.

No. 1: Ng = 1.706, Nm = 1.685, Np = 1.679, Ng ÷ Np = 0.027.
No. 2: Ng = 1.692, Nm = 1.674, Np = 1.667, Ng ÷ Np = 0.025.
No. 3: Ng = 1.696, Nm = 1.677, Np = 1.669, Ng ÷ Np = 0.027.
No. 5: Ng = 1.708, Nm = 1.692, Np = 1.686, Ng ÷ Np = 0.022.

Z ∧ c = 43°—47°. Distinct to weak axial dispersion r > v, and extinction dispersion Zv ∧ c > Zr ∧ c. Megascopic colour light green, in thin section colourless.

According to these data and to the alterations discussed below in the chapter on metamorphism, the pyroxene is a diopsidic, jadeite-bearing augite. The pyroxenes determined are all perthitized.

Garnet. Table 1 shows the results of the spectrographic analyses and the values for the specific gravity and refraction determinations. The garnets are isotropic. Megascopic colour red, in thin section red to reddish brown.

Table 1. Garnet.

	2	3	4	5
MgO	12.5	13.0		6.8
CaO	5.6	5.0		5.7
MnO	0.040	0.037		0.053
Fe_2O_3	22.3	15.0		32.0
Al_2O_3	19.0	19.5		18.7
G.	3.82	3.73	3.80	3.86
N.	1.758	1.745	1.760	1.768

Anal. A. Kvalheim, 1951. The error limit is ± 10%. Specific gravity is determined with a pycnometer and Clericis liquid, error limit ± 0.02.

The results of the spectrographic analyses are given below. The content of the bivalent and the trivalent iron has been distributed according to the garnet formula. For the sake of comparison the composition of the garnets has further been determined from Ford's diagram for grossularite, pyrope and almandine, based on specific gravity and refraction (1915, p. 42, fig. 4), and from Eskola's garnet diagram, based on refraction and type of rock (1921, pp. 9—13, fig. 1).

The composition of the garnets, based on the spectrographic analyses and the diagrams of Ford and Eskola.

No. 2.

Analysis: $(Mg_{48}Fe_{36}Ca_{16})_3\ (Al_{87}Fe_{13})_2\ (SiO_4)_{300}$
Ford: $(Mg_{50}Fe_{40}Ca_{10})_3\ Al_{200}\ (SiO_4)_{300}$
Eskola: $(Mg_{48}Fe_{34}Ca_{18})_3\ (Al, Fe)_{200}\ (SiO_4)_{300}$

No. 3.

Analysis: $(Mg_{54}Fe_{30}Ca_{16})_3\ (Al_{97}Fe_3)_2\ (SiO_4)_{300}$
Ford: $(Mg_{59}Fe_{29}Ca_{12})_3\ Al_{200}\ (SiO_4)_{300}$
Eskola: $(Mg_{56}Fe_{26}Ca_{18})_3\ (Al, Fe)_{200}\ (SiO_4)_{300}$

No. 4.

Ford: $(Mg_{42}Fe_{40}Ca_{18})_3\ Al_{200}\ (SiO_4)_{300}$
Eskola: $(Mg_{46}Fe_{36}Ca_{18})_3\ (Al, Fe)_{200}\ (SiO_4)_{300}$

No. 5.

Analysis: $(Mg_{27}Fe_{57}Ca_{16})_3\ (Al_{88}Fe_{12})_2\ (SiO_4)_{300}$
Ford: $(Mg_{40}Fe_{48}Ca_{12})_3\ Al_{200}\ (SiO_4)_{300}$
Eskola: $(Mg_{41}Fe_{41}Ca_{18})_3\ (Al, Fe)_{200}\ (SiO_4)_{300}$

ESKOLA (1921, p. 12) discusses the CaO-content. According to my investigations 18 mol. % is slightly too high a value for this type of garnet; the MgO-content will increase correspondingly. Ford's diagram gives too low figures for CaO: in that diagram the lines for refraction and specific gravity cut each other at a very acute angle. Thus when the error limits of the data are taken into account the diagram shows comparatively great differences in value, especially in the case of grossularite, but also in that of pyrope.

Amphibole. ÷ 2V = 80°—85°.

No. 1: Ng = 1.656, Nm = 1.649, Np = 1.638, Ng ÷ Np = 0.018.
No. 2: Ng = 1.651, Nm = 1.645, Np = 1.633, Ng ÷ Np = 0.018.

$Z \wedge c = 20°—25°$ Megascopic colour green. Pleocroism: X = light yellow, Y = yellowish green, Z = greenish brown. Green and bluish green colours also occur, sometimes changing within one and the same grain. Absorption: $X < Y < Z$. This is a hornblende rich in magnesia.

Chemistry.

Table 2 shows the results of the chemical analyses and the norms of specimens nos. 3 and 5 (for numbers see the chapter on mineralogy), and table 3 shows the modes of the same specimens. The sum total of the chemical analyses is somewhat high. K_2O must, moreover, be present in no. 3, as biotite occurs. The analyses are, nevertheless, included in order for some impression of the chemistry to be gained.

With regard to the mode determination it may be mentioned that the monoclinic pyroxene in no. 3 is almost entirely altered to pyroxene-plagioclase symplectite. The pyroxene in no. 5 is perthitized. The quartz content is secondary.

Table 2. Chemical analyses and norms of eclogite-amphibolites.

	3		5			3	5
	Weight%	Molprop	Weight%	Molprop		Norm	Norm
SiO_2	50.67	840	48.23	800	Ab	17.29	18.86
TiO_2	0.36	5	2.52	30	An	36.97	31.97
Al_2O_3	17.00	166	15.44	151	Qu		1.44
Fe_2O_3	1.95	12	3.85	24	sal	54.26	52.27
FeO	6.50	91	11.59	161	Il	0.76	4.56
MnO	0.17	2	0.23	3	Mt	2.78	5.57
MgO	13.03	323	6.47	161	Di	6.23	13.50
CaO	9.01	161	9.73	174	Hyp	28.62	23.96
Na_2O	2.03	33	2.24	36	Ol	7.67	
K_2O	0.00	0	0.13	1	fem	46.06	47.59
P_2O_5	tr.	0	0.20	1			
H_2O	0.27		0.40				
sum	100.99		100.93			100.32	99.86

Anal. P. Rangnes, 1951.

Table 3. Modes of eclogite-amphibolites.

	3	5
Monoclinic pyroxene	49	10
Garnet	42	8
Amphibole	3	53
Plagioclase	2	22
Epidote		x
Biotite	x	
Quartz	4	3
Apatite		x
Titanite		x
Rutile	x	x
Iron ores	x	4
Sulfides	x	x

Volume per cent. x = accessory minerals.

Metamorphism.

The rocks are metamorphic, containing several generations of minerals. It is difficult to separate the different metamorphic stages, chiefly because the later stages break down the earlier formations. A further difficulty is that the original composition is unknown, since even the least altered rock is strongly metamorphic. It is a rock which consists mainly of plagioclase and monoclinc pyroxene, the plagioclase occurring as aggregates of numerous small crystals, andesinic in composition. The pyroxene occurs as fairly large grains between the aggregates of plagioclase, and is partly altered, since the plagioclase content has been separated. Inside the aggregates of plagioclase, and especially at the pyroxene contact, some fairly small garnet porphyroblasts are seen; these must be assumed to be formed by a reaction between plagioclase and pyroxene. The rock shows further reaction rims which must have been formed later than the garnet.

It is therefore probable, from the structure, that the rock was previously non-garnetiferous, and consisted mainly of plagioclase and monoclinic pyroxene. The aggregates of small plagioclase grains often have an outline reminiscent of fairly large plagioclase laths, so that these aggregates have possibly been formed by a granulation of larger plagioclase crystals. It is further probable that the plagioclase has become more acid during such a granulation, but the writer has not been able to find any larger, more basic, plagioclase laths. A corresponding granulation, with formation of more acid plagioclase, is described by GJELSVIK (1952, p. 51, p. 55). It is probable, from the structure and the mineral composition, that the rock is a metamorphic gabbro.

From the least altered plagioclase-pyroxene rock containing some fairly small porphyroblasts of garnet, the growth of these porphyroblasts can be followed to a rock consisting mainly of garnet and pyroxene. The garnets always occur in the aggregates of plagioclase, and as the amount of garnet increases, the amount of plagioclase decreases. The garnets in the aggregates of plagioclase are generally idiomorphic, while the garnets in later metamorphic stages are usually xenomorphic, often with a shape which corresponds to the aggregates of plagioclase, since these are completely altered to garnet.

It is obvious that the garnet is formed by a reaction between plagioclase and pyroxene, mainly at the cost of plagioclase. A plagioclase-pyroxene rock is by this reaction altered to a garnet-pyroxene rock, i. e. to an eclogite.

From the microscopical investigations it can be seen that at the conclusion of this stage the rocks consisted chiefly of garnet and pyroxene. The only area where any appreciable remnants of plagioclase remained was at Silsetfjell.

The following alterations have all taken place under conditions of decreasing pressure and temperature. The pyroxene shows perthitization, symplectitization, granulation and *Sammelkristallization.* Garnet, pyroxene and plagioclase have, further, reacted with each other to form amphibole and more acid plagioclase. Owing to the presence of these minerals, formed later, it is difficult to ascertain the ratio garnet :pyroxene: plagioclase in the preceding stages. The plagioclase is altered, showing incipient saussuritization. In connection with this process two minerals have been formed which the author has not as yet been able to determine. One of these is in the form of small round grains, the other of thin thread-like particles.

The pyroxene is for the most part altered to pyroxene-plagioclase perthite, i. e. the plagioclase is separated in the form of small, parallel rods, as a rule parallel to axis c. The formation of perthite is a separation of the alkali content which has taken place at the same time throughout the whole crystal, because the lattice has not maintained the original content of jadeite at the lower P-T conditions. ESKOLA (1921, p. 72) describes a corresponding formation in pyroxene from Gimnes and Tingvoll in Nordmøre.

A part of the pyroxene is further altered to pyroxene-plagioclase symplectite. Some pyroxene grains are not attacked, while others are more or less completely altered. The symplectite grows like a sinus, with a convex boundary at the front. The intergrowth is coarser at the base of the sinus, where the growth started, and towards the front it becomes increasingly fine. The symplectite becomes steadily coarser, as the alteration progresses. An adjoining pyroxene grain showing the same extinction as the intergrowth can as a rule be found. This connection is mutual, and is to be understood as a curious reaction process between two solid phases.

Some grains show both perthitization and symplectitization, and it can be seen that the perthite must have been formed before the symplectite. Remnants of perthite rich in plagioclase are visible in the symplectite. The front of the symplectite can be seen to form small tongues between the plagioclase rods of the perthite. The alkali content of the pyroxene must have been more separated near the plagioclase rods than between them. The symplectite therefore represents a more complete separation of the alkali content. ESKOLA (1921, pp. 70—74) has described a corresponding symplectite in non-perthitized pyroxene.

The pyroxene also shows a third type of alteration, namely the granulation of some of the grains. The process by which granulation takes place is that the original pyroxene grains are broken up, from the edges inwards, into smaller grains of pyroxene, with plagiocasel grains between them. All stages of granulation can be studied, from an incipient alteration in the corners, through a continuous circle of small pyroxene grains round the older grain, to completely granulated pyroxene-plagioclase aggregates. The pyroxene grains can further be seen to grow together, thus becoming poicilitic, with inclusions of plagioclase.

Granulation is a phenomenon which corresponds to perthitization and symplectitization: the original lattice of the pyroxene has not withstood the lower P-T conditions, the pyroxene is broken up, and the plagioclase is separated.

The reactions between garnet, pyroxene and plagioclase resulting in the formation of amphibole and of a more acid plagioclase can be followed from their beginning to the stage where the rock is completely amphibolitized. In many cases there is, round the garnets, a zone of amphibole-plagioclase kelyphite with strongly varying amounts of small grains of iron ores. The amphibole is bluish green to green. This kelyphitic zone passes over into an amphibole zone, which consists of larger amphibole grains with brownish to green colours at the contact with the pyroxene and with the plagioclase aggregates. The amphibole zone of the pyroxene contact is an uralitization of the pyroxene, beginning from the border. One grain may be a part of both zones, in this case often with varying colours but with the same interference and extinction angles. This double zone is formed by the reaction between garnet and pyroxene, and between garnet and plagioclase. The kelyphitic zones are mainly formed at the expense of garnet, the amphibole zones at the expense of pyroxene or plagioclase. The various colours of the amphibole show that several phases have joined in the formation of the mineral. The brown colour of the amphibole is especially distinct when small ore grains and rutile grains are embedded, and principally at the contact to these, a phenomenon which shows that rutile and ore have also joined in the formation of the amphibole. Between pyroxene and plagioclase a reaction zone of amphibole may be developed.

The growth of these zones can be followed until all garnet, pyroxene, and aggregates of plagioclase are completely replaced. Such an amphibolitized rock may show distinct traces of the earlier minerals, the altered garnets being especially easily obeserved: they can be seen as bluish green «islands», the amphibole crystals frequently having a radial structure. The structure of the poicilitic pyroxene can also be seen after the uralitization. But as the alteration progresses, all traces of the original composition and form disappear, and eventually a granoblastic amphibolite is formed.

Mineral Facies.

It is obvious from the structure and the mineral content that the P-T conditions must originally have corresponded to those of the gabbro facies. A transition to the mineral paragenesis garnet-pyroxene is further observed. The plagioclase is unstable, and is only present where full equilibrium is not obtained. The composition of my garnets and pyroxenes shows, according to Eskola's values (1920, p. 155), that they are critical for the eclogite facies, and that the alteration has certainly taken place under the P-T conditions of this facies.

After this increasing metamorphism, the rocks have undergone a diaphtorism under steadily sinking P-T conditions. The perthitization, symplectitization, granulation and S*ammelkristallization* of the pyroxene are alterations which have taken place under the conditions of the hornfels facies. The reactions between garnet, pyroxene and plagioclase, with the formation of amphibole and more acid plagioclase, show that the alterations have continued into the amphibolite facies. The saussuritization of the plagioclase shows that the diaphtorism has at last reached the epidote amphibolite facies.

Genesis.

In those parts of the Norwegian folding zone where the rocks are known to be Cambro-Silurian, we find both gabbros and basaltic rocks covering vast areas. This is the case both in Trøndelag and in Bergen—Hardanger. The maps of the Bergen Arcs demonstrate how these basic rocks may be interspersed with gneisses, schists etc. in a very intricate way. If we assume that the basic rocks of the North-Western Gneiss Area are of Caledonian age, it is natural to believe that their genesis does not differ very much from that of the corresponding rocks from the districts of recognized Caledonian age. We are thus *a priori* inclined to believe that the basic rocks of the North-Western Gneiss Area may originally have been gabbros and basalts. As these rocks at present occur as amphibolites, eclogite-amphibolites, eclogites etc., it is one of the aims of research in this area to find out what these rocks originally were.

GJELSVIK (1952) has described some basic rocks of Sunnmøre as metamorphic diabases or dolerites.

With regard to the eclogite-amphibolite of the Molde peninsula, their mode of occurrence, in connection with the marble, might point to a volcanic origin. But the structure of the eclogite-amphibolite indicates that the rock was originally a gabbro.

On the basis of the following considerations the author suggests quite a different theory.

The gneiss shows a transition from quartzdioritic composition through granodioritic to granitic both from the south and the north towards the eclogite-amphibolite. Considerable amounts of augengneiss occur near the eclogite-amphibolite. As mentioned in the chapter on the gneiss, the amount of Fe, Mg, Ca and Na has decreased in the granitic gneisses, and these ions must have penetrated into a bordering rock. The eclogite-amphibolite borders directly onto these gneisses, it contains considerable amounts of these ions, and again borders onto marble, which has a great capacity of adsorption. According to this theory the eclogite-amphibolite will be a granitization front and a skarn formation. But the investigations are as yet not sufficiently complete to allow of any elaboration of this hypothesis.

Nomenclature.

It is difficult to find a satisfactory generic name for the entire basic rock complex. The writer hesitates to use the term meta-gabbro, since the origin of the rocks is not known, and therefore suggests the term eclogite-amphibolite, from the dominating mineral parageneses, as a common name for the basic rock types.

COMPARISON WITH THE ECLOGITE-HORNBLENDE GABRO.

It was Eskola who (1921, p. 43) introduced the term, eclogite-hornblende gabbro. One of the specimens he has studied is from Brandsæterbotn (p. 19, p. 79, p. 116, Pl. III, fig. 13), a place in the Tverrfjellene mountains. According to my investigations Brandsæterbotn consists of eclogite-amphibolite, marble, and gneiss.

I have had the opportunity of studying the thin section of which the microphoto Pl. III, fig. 13 of Eskola's paper shows a part. It corresponds completely to my eclogite-amphibolite, and the rock can be placed in my metamorphic series. The rock previously consisted only of pyroxene and garnet, and was a true eclogite. Amphibole and plagioclase were formed later, along the borders of the grains.

ESKOLA arranges the minerals in the same succession, but he is of the opinion that the rock is magmatic in origin, with garnet and pyroxene as the first crystallized minerals. He is, however, somewhat in doubt as to the magmatic nature of amphibole and plagioclase (p. 80). The supposition of a magmatic origin for the eclogite-hornblende gabbro is in accordance with the result of his other eclogite studies.

GJELSVIK (1952, pp. 48—58) describes a metamorphism of dolerites. He finds that the metamorphism as a whole has taken place under P-T conditions which correspond to a field between granulite and eclogite facies (p. 106). In accordance with these investigations he assumes that the eclogite-hornblende gabbro «is not an altered eclogite, but an altered dolerite in transition to eclogite» (p. 124).

Gjelsvik's paper makes no mention of the possibility of varying P-T conditions during the metamorphism of the dolerites, a possibility which does seem to be present from his description. The supposition, more probable from the structural point of view, that the eclogite-hornblende gabbro is an altered eclogite, might then be stated.

ON THE AGE OF THE MOLDE PENINSULA.

There can be no doubt that the rocks on the Molde islands south of the peninsula are Cambro-Silurian. This is a syncline, which owes its present character to the Caledonian orogeny. The gneisses at Molde are conformable to this syncline, and must have assumed their present appearance at the same time, because no movements of any regional character have taken place since granitization.

If the eclogite-amphibolite is considered to be metamorphic basalt or gabbro, then the eclogite-amphibolite, together with the marble and the surrounding gneisses, may be of a Cambro-Silurian formation analogous to the Molde syncline, but quite different in character from the latter owing to the higher P-T conditions.

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N. G. U.: Norges Geologiske Undersøkelse.

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PLATES 1—4

EXPLANATION OF THE PLATES.

The photomicrographs represent different stages of the metamorphic eclogite-amphibolite series. They were all taken with unpolarized light and magnif. 12 x. Photographer: Miss E. IRGENS.

PLATE 1.

Fig. 1. Aggregates of small plagioclase grains and pyroxene. The pyroxene shows perthitization. Amphibole is formed at the plagioclase-pyroxene contact. Silsetfjell.

Fig. 2. Aggregates of small plagioclase crystals and perthitized pyroxene. Garnets occur in the aggregates of plagioclase. Amphibole is formed at the contacts of the plagioclase, pyroxene and garnet. Silsetfjell.

PLATE 2.

Fig. 1. Perthitized and symplectitized pyroxene and garnet. Between these minerals are formed amphibole and plagioclase. Stortuva, Silsetfjell.

Fig. 2. Pyroxene, completely altered to pyroxene-plagioclase symplectite, and xenomorphic garnet with amphibole-plagioclase kelyphite. Bollia.

PLATE 3.

Fig. 1. Pyroxene and garnet. The pyroxene shows perthitization and incipient granulation. Between these minerals amphibole and plagioclase are formed. Visnes.

Fig. 2. Pyroxene and garnet. The pyroxene shows incipient symplectitization. Between these minerals are formed amphibole and plagioclase. Tverrfjellene.

PLATE 4.

Fig. 1. Remnants of pyroxene, almost completely altered to symplectite, and of garnet with amphibole kelyphite. Between these minerals amphibole and small grains of plagioclase are formed. Langnes.

Fig. 2. Amphibole and plagioclase. Altered garnets are seen as aggregates of small orientated amphibole crystals. Silsetfjell.

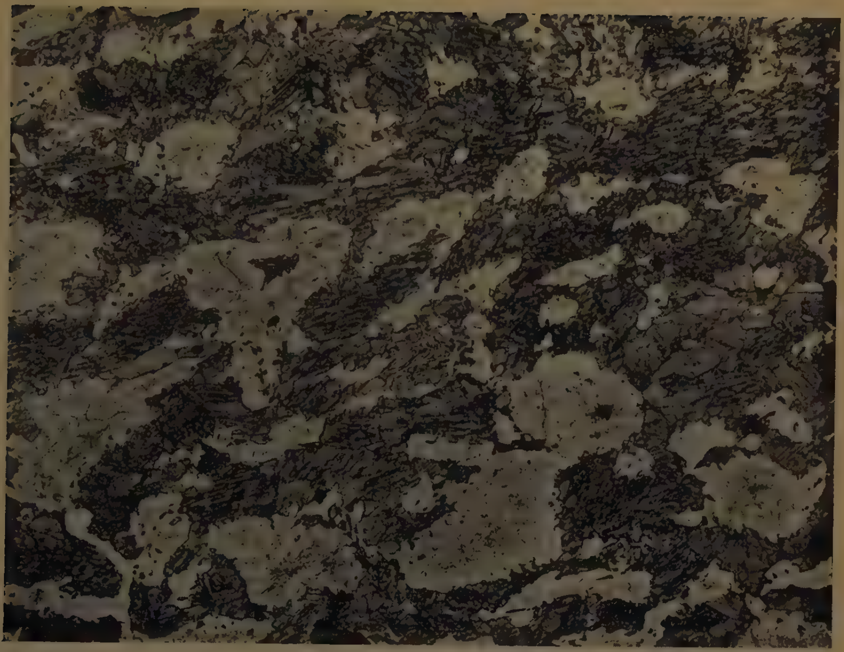

Fig. 1

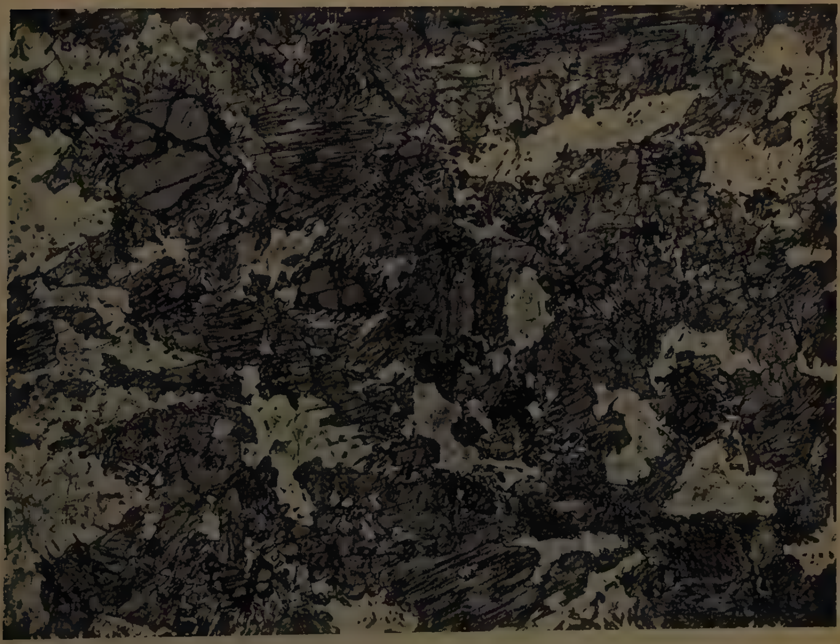

Fig. 2

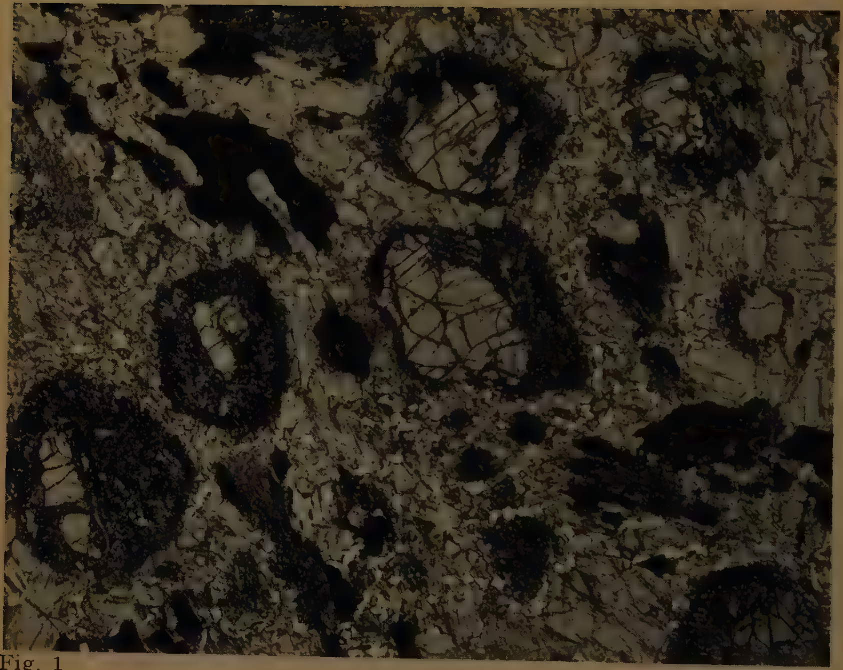

Fig. 1

Fig. 2

THE STRATIGRAPHIC POSITION OF THE QUICK CLAY AT BEKKELAGET, OSLO

BY

ROLF W. FEYLING-HANSSEN

(University of Oslo)

With three text-figures and one plate.

Abstract: The foraminiferal content of two clay samples, one from the quick clay at Bekkelaget (sample nr. 1142) and one from the underlying deposit (sample nr. 1145), was examined for stratigraphic determination of the deposits. The quick clay appeared to be of Post-Glacial age (*Isocardia*-clay), whereas the underlying one was of Late-Glacial age.

Analyses.

A sample of the quick clay from Bekkelaget (5 km southeast of Oslo centre) was handed over to me by Curator H. ROSENDAHL for stratigraphic determination, as good megafossils were lacking. The clay had been pressed up to the surface, 6 m above sea level, by the landslide on October 7th, 1953, and was fluid.

The foraminiferal content of the clay sample was rich, and revealed at once the Post-Glacial character of the sediment. It is an *Isocardia*-clay deposited during the Post-Glacial warm period.

The mechanical analysis (50 g of the sample treated) gave the following result:

Grade fraction	Percentage
< 125.0 μ	99
« 74.0 «	97
« 45.3 «	94
« 35.3 «	92
« 26.9 «	89
« 17.9 «	86
« 9.4 «	74
« 6.8 «	66
« 4.9 «	57
« 2.5 «	42
« 1.1 «	28

Median diameter, $M = 3.7\,\mu$. Quartiles, $Q_3 = 9.8\,\mu$, $Q_1 = 0.8\,\mu$. Coefficient of sorting, $So = \sqrt{Q_3/Q_1} = 3.5$, *i. e.* normal sorting (TRASK 1932). Coefficient of quartile skewness, $Sk = Q_1Q_3/M^2 = 5.7$, *i. e.* the maximum sorting lies on the fine side of the median diameter (fig. 1, nr. 1142).

For micropaleontological investigation another part of the sample was placed, for some hours, in a solution of H_2O_2 and then sieved through a 0.1 mm sieve. Of the residuum three extraction trays were examined, from which 1000 specimens of Foraminifera were picked out. Additionally some ostracod valves were present, and also one tergum of a small specimen of the cirriped *Verruca stroemia* (O. F. MÜLLER 1776).

The foraminiferal analysis gave the following result:

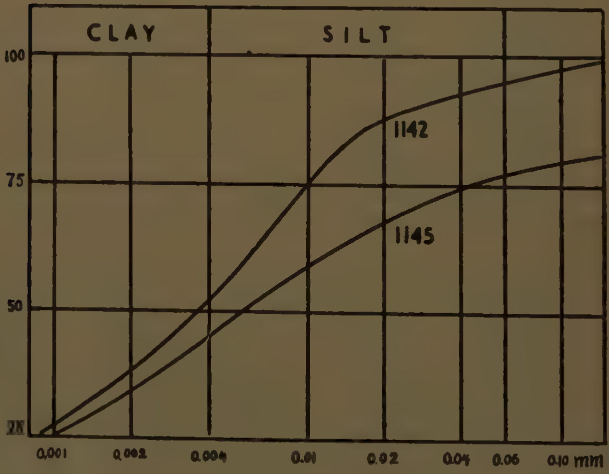

Fig. 1.
Cumulative-frequency curves of the quick clay (sample nr. 1142), and the underlying clay (sample nr. 1145), from Bekkelaget, Oslo.

Bekkelaget. Quick clay. Sample nr. 1142.

Foraminifera	Frequency	Percentage
Bulimina marginata D'ORBIGNY	581	58.1
Cassidulina laevigata D'ORBIGNY	160	16.0
Elphidium incertum (WILLIAMSON)	124	12.4
Elphidium clavatum CUSHMAN	41	4.1
Lagena elongata distoma PARKER and JONES	15	1.5
Nonion pompilioides (FICHTEL and MOLL)	12	1.2
Virgulina fusiformis (WILLIAMSON)	12	1.2
Streblus beccarii (LINNAEUS)	10	1.0
Cibicides pseudoungerianus (CUSHMAN)	9	0.9
Quinqueloculina seminulum (LINNAEUS)	8	0.8
Eponides exiguus (BRADY)	8	0.8
Elphidium cf. *selseyensis* HERON-ALLEN and EARLAND	5	0.5
Globobulimina turgida (BAILEY)	4	0.4
Triloculina trigonula (LAMARCK)	3	0.3
Nonionella turgida (WILLIAMSON)	2	0.2
Rheophax sp. (fragment)	1	0.1
Triloculina tricarinata D'ORBIGNY	1	0.1
Ophthalmidium inconstans (BRADY)	1	0.1
Lagena striata substriata (WILLIAMSON)	1	0.1
Uvigerina peregrina CUSHMAN	1	0.1
Cassidulina crassa D'ORBIGNY	1	0.1
	1000	100.0

The fauna thus contained 21 species, clearly dominated by *Bulimina marginata*. All of these species but one, were recorded from the *Isocardia*-clay of the Oslofjord area (FEYLING-HANSSEN 1954). *Triloculina tricarinata* D'ORBIGNY was not found there; it was originally described from the Red Sea (Cf. p. 189). There was a remarkably high frequency of *Cassidulina laevigata;* they were all carinated and most of them nearly opaque (Cf. pp. 193-194.).

The foraminiferal fauna of the quick clay from Bekkelaget indicates that the clay was deposited during the Post-Glacial warm period (Atlantic-Subboreal age) in fairly well ventilated water, at a depth of about 40—100 m (Cf. *i. a.* BARTENSTEIN 1938; BRAND 1941; HÖGLUND 1947, p. 295; VOORTHUYSEN 1949 and 1950).

Borings carried out by Norges Geotekniske Institutt (Civil engineer L. Bjerrum) revealed another clay sediment below the quick clay. A sample of this clay from core level 12.5 m was handed over to me by Dr. I. Rosenqvist.

From the mechanical analysis (done by Norges Geotekniske Institutt) appeared: Median diameter, $M = 5.6\ \mu$; quartiles, $Q_3 = 45.0\ \mu$, $Q_1 = 1.0\ \mu$; coefficient of sorting, $So = 6.7$, *i. e.* poorly sorted; coefficient of quartile skewness, $Sk = 1.4$, *i. e.* the maximum sorting lies on the fine side of the median diameter (fig. 1, nr. 1145).

The foraminiferal content of the sample was poor. Examination of 12 extraction trays yielded only 302 specimens of Foraminifera. Additionally a few ostracod valves were present and also some fragments and juvenile valves of the pelecypod *Yoldiella lenticula* (Møller) (= *Portlandia lenticula* (Møller)).

The foraminiferal analysis gave the following result:

Bekkelaget. Clay, core level 12.5 m. Sample nr. 1145.

Foraminifera	Frequency	Percentage
Cassidulina laevigata d'Orbigny	72	23.8
Cassidulina crassa d'Orbigny	66	21.9
Elphidium clavatum Cushman	36	11.9
Pullenia osloensis Feyling-Hanssen	34	11.3
Virgulina loeblichi sp. n.	32	10.4
Pyrgo cf. *simplex* (d'Orbigny)	16	5.3
Quinqueloculina stalkeri Loeblich and Tappan	13	4.3
Quinqueloculina seminulum (Linnaeus)	6	2.0
Lagena striata striata (d'Orbigny)	5	1.7
Lenticulina sp.	5	1.7
Nonion labradoricum (Dawson)	5	1.7
Pyrgo williamsoni (Silvestri)	3	1.0
Virgulina sp.	3	1.0
Lagena laevis (Montagu)	2	0.7
Quinqueloculina arctica Cushman	1	0.3
Triloculina trihedra Loeblich and Tappan	1	0.3
Lagena elongata distoma Parker and Jones	1	0.3
Elphidium incertum (Williamson)	1	0.3
	302	99.9

The fauna contained 18 species, dominated by *Cassidulina laevigata* (Cf. p. 193) and *Cassidulina crassa. Elphidium clavatum, Pullenia osloensis* (Cf. p. 194), and *Virgulina loeblichi* sp. n. were frequently represented.

All identified species occur at present in Arctic and sub-Arctic waters. This indicates Late-Glacial age of the sediment. The comparatively large number of species suggests an age younger then that of the *Yoldia*-clay. The presence of *Pullenia osloensis* places the sediment somewhere within the range of the *Arca*-clay (FEYLING-HANSSEN 1954).

This underlying clay was also deposited in fairly well ventilated water.

Remarks on some of the species.

Triloculina tricarinata D'ORBIGNY 1826.

This species differs from *Triloculina trihedra* LOEBLICH and TAPPAN and *T. trigonula* (LAMARCK) in having distinctly concave, excavated sides, and acute angles. It was originally described from the Red Sea (D'ORBIGNY 1826, p. 299).

One specimen in the quick clay (Post-Glacial warm period, sample nr. 1142. It was unfortunately broken when I tried to mount it for photographing).

Pyrgo williamsoni (SILVESTRI 1923).

Plate 1, figs. 1—3.

LOEBLICH and TAPPAN 1953, p. 48, pl. 6, figs. 1—4.

Description (after LOEBLICH and TAPPEN 1953, p. 48): «Test oval in outline, inflated; chambers oval in outline, the last extending beyond the previous on all margins, the young specimens somewhat more elongate, the larger ones nearly circular; sutures distinct, depressed; wall calcareous, white, imperforate and vitreous in appearance, surface smooth; aperture ovate with a small, broad, and bifid tooth projecting from the inner and lower margin of the aperture, the tooth more strongly bifid in the older specimens».

Remarks: Three specimens occurred in sample nr. 1145 (Late-Glacial). The largest one (Pl. 1, fig. 1) had a length of 0.45 mm, a breadth of 0.30 mm, and a thickness of 0.27 mm. They were all oval in outline with a nearly circular aperture and spatulate tooth.

Pyrgo cf. *simplex* (D'ORBIGNY 1846).

Plate 1, figs. 4—6, text-fig. 2.

GOËS 1894, p. 116, pl. 22, fig. 885.

Description: Test nearly circular in outline, much inflated; chamber development biloculine, the last chamber extending beyond the penultimate one on all margins; sutures distinct, depressed; wall calcareous, imperforate, surface smooth; aperture broad, curved, with a broad and thin tooth, or rather lip, projecting from the surface of the previous chamber, the lip lacking in many specimens, probably due to its fragility.

Remarks: 16 specimens were picked out from sample 1145 (Late-Glacial). The specimen of Pl. 1, fig. 5, which was a small one, measured: length 0.32 mm, breadth 0.22 mm, thickness 0.13 mm. Length of specimen of fig. 6, 0.35 mm, breadth 0.27 mm, thickness 0.26 mm.

Examination of specimens lacking the apertural lip, proved that it was usually preserved in the earlier developmental stages.

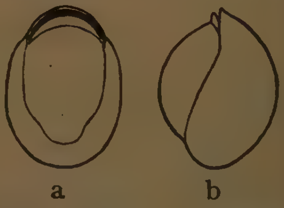

Fig. 2. *Pyrgo* cf. *simplex* (D'ORBIGNY), a, front view, b, side view of a specimen from the Late-Glacial of Bekkelaget.

Lagena elongata distoma PARKER and JONES 1864.

Plate 1, fig. 7.

15 specimens were present in the quick clay, sample nr. 1142 (Post-Glacial), and one in the sample from the underlying clay (nr. 1145).

The figured specimen is that from the underlying clay. Its length was 1.40 mm, breadth 0.14 mm. It was more elongate than the Post-Glacial specimens.

Lagena laevis (MONTAGU 1803).

Plate 1, fig. 8.

Two specimens were present in sample nr. 1145 (Late-Glacial). Length of specimen of fig. 8, 0.49 mm, thickness 0.19 mm.

Lagena striata striata (D'ORBIGNY 1839).

Plate 1, figs. 9, 10.

Five specimens were present in the Late-Glacial sample. Length of specimen of fig. 9, 0.37 mm, thickness 0.17 mm; length of specimen of fig. 10, 0.38 mm, thickness 0.15 mm.

Lenticulina species.

Plate 1, figs. 11—13.

Description: Test almost semicircular in outline, moderately compressed, periphery subacute to rounded; chambers 4—5, increasing rapidly in height as added; sutures distinct, slightly depressed; wall hyaline, surface smooth; aperture radiate, at the dorsal angle.

Length of specimen of fig. 11, 0.30 mm, breadth 0.19 mm, thickness 0.11 mm; length of specimen of fig. 12, 0.24, mm, breadth 0.18 mm, thickness 0.11 mm; length of specimen of fig. 13, 0.27 mm, breadth 0.19 mm, thickness 0.12 mm.

Remarks: Five small specimens occurred in the sample of the underlying clay. They were most probably juveniles.

Virgulina loeblichi new species.

Plate 1, figs. 14—18, text-fig. 3.

Bulimina exilis BRADY—LOEBLICH and TAPPAN 1953, p. 110, pl. 20, figs. 4, 5.

Virgulina cf. *davisi* CHAPMAN and PARR—FEYLING-HANSSEN 1954, p. 132, pl. 1, figs. 12 a, b.

Description: Test elongate, 3—4 times as long as broad, biserial throughout both in microspheric and megalospheric form, very seldom triserial in the earliest stages, twisted, tapering towards the sometimes slightly apiculate initial end, no spines; chambers about 10, inflated, elongate, increasing rather rapidly in size as added; sutures distinct, depressed; wall calcareous, very finely and densely perforate, more or less translucent, surface smooth; aperture large, broad, but elongate.

Length of holotype, fig. 14, 0.54 mm, breadth 0.18 mm. Length of paratype of fig. 15, 0.55 mm, breadth 0.15 mm; length of paratype of fig. 16, 0.54 mm, breadth 0.16 mm; length of paratype of fig. 17, 0.47 mm, breadth 0.15 mm; length of paratype of fig. 18 (microspheric form), 0.48 mm, breadth 0.16 mm.

Holotype: Paleontological museum, Oslo, Fo. 1145 A.

Type stratum and locality: *Arca*-clay of the Late-Glacial from Bekkelaget, Oslo, 12.5 m below surface.

Derivation of name: This species is named in honour of ALFRED R. LOEBLICH, JR., U. S. National Museum.

Occurrence: 32 specimens were picked out from the sample of *Arca*-clay from Bekkelaget. It was present in several samples of Late-Glacial age, viz. *Yoldia*-clay and *Arca*-clay, from the Oslofjord area, frequently in the *Arca*-clay (FEYLING-HANSSEN 1954, recorded as *Virgulina* cf. *davisi*).

Its main recent distribution is probably arctic (LOEBLICH and TAPPAN 1953, p. 110).

Remarks: Only in a very few specimens I have observed a triserial arrangement in the very earliest portion of the test, the others were biserial throughout. Most of them were rather strongly twisted. Many of the megalospheric specimens were broadest towards the middle of the test, whereas the microspheric forms tapered more regularly, being broadest at the apertural end.

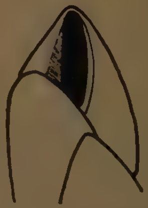

Fig. 3. *Virgulina loeblichi* sp.n. Apertural view of a specimen from the *Yoldia*-clay of Jomfruland (sample nr. 1017).

This species shows affinities to *Virgulina nodosa* R. E. and K. C. STEWART (1930, p. 64, pl. 8, figs. 4a—c) from the Late Tertiary of California and Mexico (Cf. CUSHMAN 1937, p. 22, pl. 3, figs. 24a—c), from which it differs in the broader aperture (Cf. text-fig. 3) and in the more elongate chambers.

It has also much in common with *Virgulina complanata* EGGER (1893, p. 292, pl. 8, figs. 91, 92) from Western Australia (Cf. CUSHMAN 1937, p. 26, pl. 4, figs. 13—17), from which the present species differs in being smaller, less compressed, twisted throughout, and having more inflated chambers.

Virgulina loeblichi sp. n. has probably also been recorded as *Virgulina schreibersiana* CZJZEK 1847.

Virgulina species.

Plate 1, figs. 23, 24.

Description: Test elongate with nearly parallel sides, lowest part tapering towards the initial end, biserial, slightly compressed, periphery rounded, earlier part of the test slightly, if at all, twisted; chambers about 9, elongate; sutures quite distinct, depressed; wall calcareous, thin, finely perforate, translucent to hyaline, surface smooth; aperture large, at the end of the last formed chamber, tending to become terminal.

Length of specimen of fig. 23, 0.45 mm, breadth 0.13 mm; length of specimen of fig. 24, 0.45 mm, breadth 0.12 mm.

Remark: 3 specimens were present in the sample of Late-Glacial clay from Bekkelaget.

Cassidulina crassa D'ORBIGNY 1839.

Plate 1, figs. 19, 20.

66 specimens were picked out from the Late-Glacial clay sample (nr. 1145).

Length of specimen of fig. 19, 0.28 mm, thickness 0.16 mm; length of specimen of fig. 20, 0.29 mm, thickness 0.16 mm.

Only a single specimen of this species occurred in the sample from the overlying quick clay from the Post-Glacial warm period.

Cassidulina laevigata D'ORBIGNY 1826.

Plate 1, figs. 21—22 and 25—32.

The specimens from the Late-Glacial, *Arca*-clay, (figs. 27—32) are closely related to *Cassidulina teretis* TAPPAN 1951. They have a peripheral keel and translucent wall. They are also slightly evolute so that an umbonal boss occurs, «through which may be seen the earlier whorls...» (LOEBLICH and TAPPAN 1953, p. 121). But that condition is usually to be found only on one side of the test; on the opposite side the chambers extend more or less completely over the central portion.

Such specimens were found also in *Yoldia*-clay from the Oslofjord area (FEYLING-HANSSEN 1954, pl. 2, figs 2a—b). In samples of *Yoldia*-clay there also occurred specimens of *C. norcrossi* CUSHMAN, 1933.

Length of specimen of fig. 27, 0.29 mm, thickness 0.11 mm; length of specimen of fig. 28, 0.31 mm, thickness 0.12 mm; length of specimen of fig. 29, 0.35 mm, thickness 0.15 mm; length of specimen of fig. 30, 0.28 mm, thickness 0.12 mm; length of specimen of fig. 31, 0.30 mm, thickness 0.13 mm; length of specimen of fig. 32, 0.38 mm, thickness 0.14 mm.

In the overlying quick clay, of Post-Glacial age, the specimens of *C. laevigata* were still lenticular with a peripheral keel, but most of them were nearly opaque with very indistinct sutures (figs. 25—26); some were partly translucent (figs. 21—22). The chambers usually extended over the central portion on both sides of the test.

Length of specimen of fig. 21, 0.34 mm, thickness, 0.16 mm; length of specimen of fig. 22, 0.30 mm, thickness, 0.14 mm; length of specimen of fig. 25, 0.42 mm, thickness 0.19 mm; length of specimen of fig. 26, 0.35 mm, thickness 0.14 mm.

The specimens here referred to *C. laevigata* were frequent in the lower, Late-Glacial, clay as well as in the overlying quick clay, of Post-Glacial age.

Pullenia osloensis FEYLING-HANSSEN 1954, new name.

Plate 1, figs. 33—35.

Pullenia quinqueloba minuta FEYLING-HANSSEN 1954, p. 133, pl. 2, fig. 3a, b.

34 specimens were picked out from the sample of the lower, Post-Glacial, clay from Bekkelaget.

Length of the specimen of figs. 34 and 35, 0.19 mm, thickness 0.13 mm.

Remarks: This species has been given the new name *P. osloensis*, after its type locality, because *P. quinqueloba minuta* was preoccupied by *P. minuta* CUSHMAN 1936 (Contr. Cushman Lab. Foram. Research, vol. 12, p. 77, pl. 13, fig. 7) for an Upper Cretaceous form of Texas (kindly pointed out by Prof. Dr. HANS E. THALMANN of Stanford University). It has been raised to specific rank because further examination of *Pullenia*-bearing material proved its distinct difference from other species of the genus.

Nonion labradoricum (DAWSON 1860).

Five specimens were present in the Late-Glacial clay. They were small for the species.

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Manuscript received February 17, 1954.

PLATE 1.

Figs. 1—3. *Pyrgo williamsoni* (SILVESTRI) .... p. 189
1, Front view of largest specimen (nr. 1145 b), 2, 3, Front view and side view of another specimen (nr. 1145 b); both from the Late-Glacial of Bekkelaget, Oslo.

Figs. 4—6. *Pyrgo* cf. *simplex* (D'ORBIGNY) .... p. 190
5, Front view showing the broad apertural lip, 4, 6, Side view, three different specimens (nr. 1145 c) from the Late-Glacial of Bekkelaget.

Fig. 7. *Lagena elongata distoma* PARKER and JONES .... p. 190
Specimen (1145 d) from the Late-Glacial of Bekkelaget.

Fig. 8. *Lagena laevis* (MONTAGU) .... p. 191
Specimen (nr. 1145 e) from the Late-Glacial of Bekkelaget.

Figs. 9, 10. *Lagena striata striata* (D'ORBIGNY) .... p. 191
Two specimens (nr. 1145 f) from the Late-Glacial of Bekkelaget.

Figs. 11—13. *Lenticulina* species .... p. 191
Side view of three different specimens (nr. 1145 g) from the Late-Glacial of Bekkelaget.

Figs. 14—18. *Virgulina loeblichi* new species .... p. 191
14, Side view, showing the aperture, of holotype (nr. 1145 A). 15—18, Side view of paratypes (nr. 1145 h). 14—17, Megalospheric forms, 18, Microspheric form. All from the Late-Glacial of Bekkelaget.

Figs. 19, 20. *Cassidulina crassa* D'ORBIGNY .... p. 193
19, Dorsal view, 20, ventral view, of two specimens (nr. 1145 k) from the Late-Glacial of Bekkelaget.

Figs. 21, 22, 25—32. *Cassidulina laevigata* D'ORBIGNY .... p. 193
21, 22. Semitranslucent specimens from the quick clay of Post-Glacial age, ventral and dorsal view. 25, 26. Two opaque specimens (nr. 1142 b) from the Post-Glacial quick clay from Bekkelaget, peripheral and ventral view. 27—32, Translucent specimens (nr. 1145 m) from the underlying Late-Glacial clay.

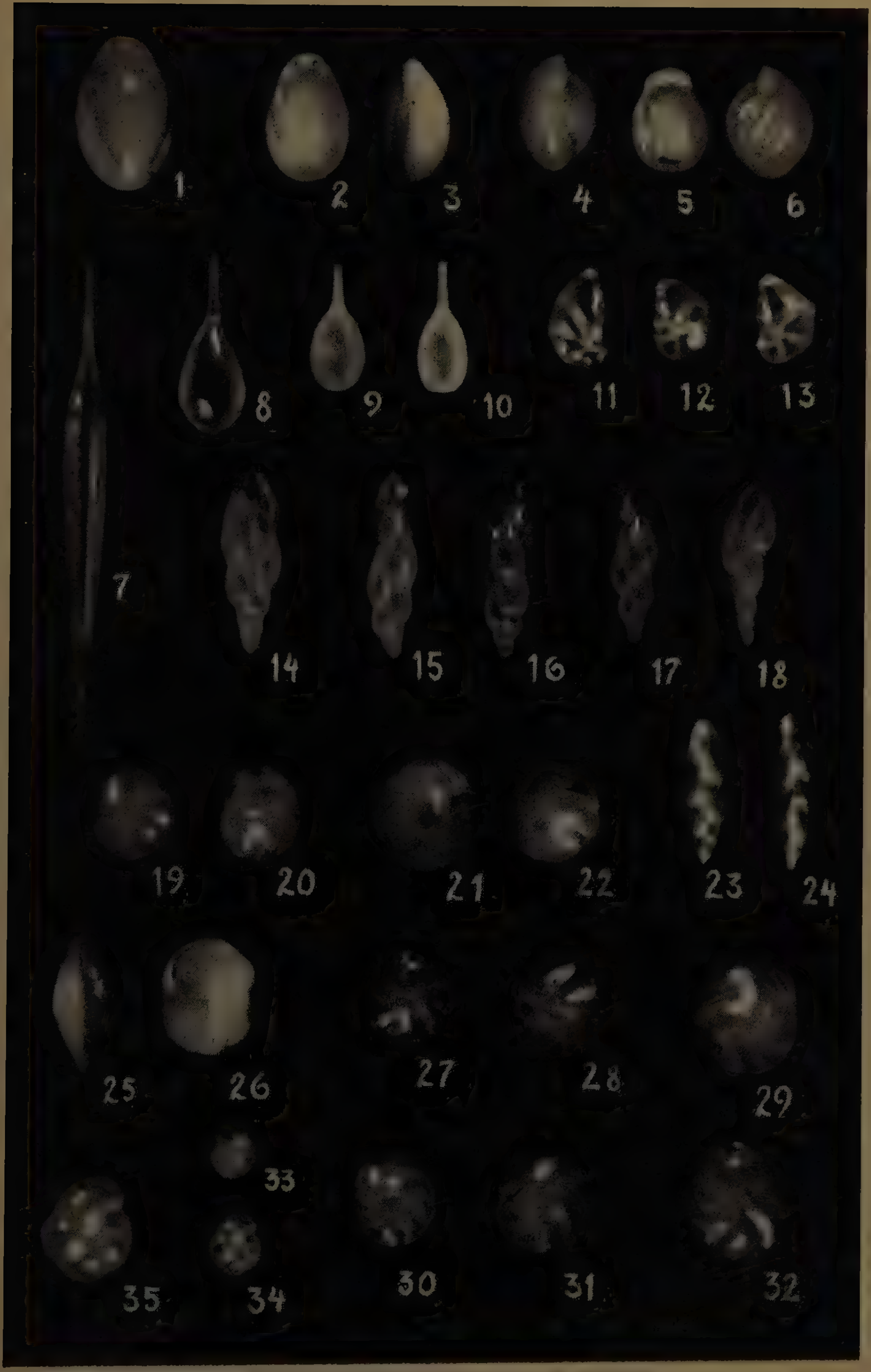
Figs. 23, 24. *Virgulina* species .... p. 193
Side view of two specimens (nr. 1145 n) from the Late-Glacial of Bekkelaget.

Figs. 33—35. *Pullenia osloensis* FEYLING-HANSSEN .... p. 194
33, 34, Side view of two specimens (nr. 1145 p) from the Late-Glacial of Bekkelaget, lobulate forms. 35, The same as 34 in double magnification.

Figs. 1 — 34 × 45. Fig. 35 × 90.

The photographs for the plate were prepared by the Faculty photographer, Miss BERGLIOT MAURITZ

PLATE 1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SYSTEMET $CaO-SiO_2-H_2O$

AV

GUNNAR KULLERUD
(Mineralogisk-Geologisk Museum, Oslo).

Abstract. A study of the system $CaO—SiO_2—H_2O$ is important for an understanding of the chemistry of Portland cement. The literature dealing with compounds in this system is reviewed and the stability conditions for individual hydrates discussed. Tentative phase diagrams for the systems $CaO \cdot SiO_2—H_2O$ and $2CaO \cdot SiO_2—H_2O$ are given from data recorded in the literature and from laboratory experiments carried out at the Geological Museum, Oslo.

Some of the hydrates of the second system gradually give off water with increasing temperature and in this respect resemble certain clay minerals e. g. montmorillonite. Hydrates of the first system, however, show a tendency to lose water in stages.

Innledning.

Spredte undersøkelser innen dette system er foretatt fra tid til annen i hydrotermallaboratorier i mange land. Den viktigste litteratur om hydrotermalsynteser ble sammenstillet av MOREY og INGERSON[1] i 1937. TAYLOR og BESSEY[2] publiserte i 1950 en oversikt over de inntil da kjente reaksjoner i $CaO—SiO_2—H_2O$ systemet. Nærværende artikkel er bygget over de nevnte to arbeider, men dekker også litteraturen etter 1950 og inneholder dessuten endel tidligere upubliserte resultater av undersøkelser i systemet utført med hydrotermal-apparaturen (av Tuttle-typen) ved Geologisk Museum, Oslo.

Forbindelser tilhørende det binære system $CaO—SiO_2$ er inngående beskrevet i litteraturen og vil ikke her bli gjenstand for diskusjon i større utstrekning enn nødvendig for sammenhengen.

En gjennomsnitts Portland sement inneholder ca. 64.0 % CaO, 5.6 % Al_2O_3 og 21.1 % SiO_2. Til tross for den utstrakte anvendelse av sement kjenner man lite til de kjemiske reaksjoner som foregår i denne under avbinding og herding. Opplysninger om disse reaksjoner kan skaffes gjennom inngående undersøkelser av systemer som $CaO—SiO_2—H_2O$ og $CaO—Al_2O_3—SiO_2—H_2O$. Av disse er det sistnevnte det viktigste, men også uten sammenligning det mest kompliserte. Undersøkelser av forbindelsene er vanskelige å gjennomføre på grunn av hydratenes komplekse natur og deres gelatinøse eller dårlig definerte form.

Den viktigste gruppe av slike forbindelser er kalsium-silikathydratene som opptrer som amorfe eller gellignende substanser ved romtemperatur, men under hydrotermalprosesser ved noe høyere temperatur frembringes en variasjon av tydelig krystallinske forbindelser. Disse bør undersøkes først, da de ofte strukturmessig er beslektet med lav-temperatur-produktene, hvis egenskaper man derved undertiden kan finne frem til en forståelse av.

Hydratene som dannes i $CaO—SiO_2—H_2O$ systemet er også av interesse for geokjemien og rent teknisk viktige ved dannelser av kjelsten[3] i dampkjeler og ved produksjonen av «sand-lime» blokker[4,5,6].

Undersøkelsene som hittil har vært foretatt i systemet faller i tre grupper:

1. Undersøkelser av hydrater som forekommer i naturen.
2. Studier av hydreringsreaksjoner og undersøkelser av forbindelser dannet under 30° C.
3. Studier av hydrotermalreaksjoner over 100° C.

Lite eller intet er gjort for å knytte sammen resultatene oppnådd ved undersøkelser av amorfe forbindelser dannet under 30° C med resultatene av studiene av de krystallinske hydrater dannet over 100° C. Praktisk talt ingen forsøk er foretatt ved temperaturer mellom 30° C og 100° C.

Systemets Hydrater.

En rekke kalsium-silikat-hydrater er allerede beskrevet i litteraturen, men undersøkelser i de siste to årene har vist at det eksisterer et langt større antall hydrater enn tidligere kjent. Mange av disse

Mineral	Sammensetning	Krystall symmetri	Lysbrytning			Spesifikk vekt	Andre egenskaper
			α	β	γ		
Okenit	$CaO \cdot 2SiO_2 \cdot 2H_2O$	triklin	1.512	1.514	1.515	2.28—2.33	
Gyrolit	$2CaO \cdot 3SiO_2 \cdot 2H_2O$	heksagonal (lamellær)	1.535	—	1.545	2.34—2.45	a=9.72, c=132.8 Å romgruppe C6, $z=48$
Xonotlit	$5CaO \cdot 5SiO_2 \cdot H_2O$	monoklin	1.583	1.585	1.595	2.70	
Crestmoreit	$2CaO \cdot 2SiO_2 \cdot 3H_2O$	monoklin	1.593	1.603	1.607	2.60	
Foshagit	$5CaO \cdot 3SiO_2 \cdot 3H_2O$	rombisk	1.594	1.594	1.598	2.67	
Afwillit	$3CaO \cdot 2SiO_2 \cdot 3H_2O$	monoklin	1.617	1.620	1.634	2.643 ± 0.005	a=16.27, b=5.632, c=13.23 Å, β=134°48, romgruppe Cc
Hillebrandit	$2CaO \cdot SiO_2 \cdot H_2O$	rombisk	1.605	1.610	1.612	2.67	a=16.60, b=7.26 c=11.85 Å. $z=12$
Riversideit	$2CaO \cdot 2SiO_2 \cdot H_2O$	rombisk(?)	1.600	1.601	1.605	2.64	a=9.6 Å
Tombermorit	$CaO \cdot SiO_2 \cdot H_2O$	rombisk	1.570	1.571	1.575	—	a=γ, b=β, c=α a=11.3, b=7.33, c=22.6 Å romgruppe C222
Plombierit	$2CaO \cdot 2SiO_2 \cdot 5H_2O$	—	—	—	—	—	a=14.6 Å

er metastabile og kompliserer derfor utarbeidelsen av $CaO—SiO_2—H_2O$ diagrammet.

A. HYDRATER SOM FOREKOMMER I NATUREN.

Hittil er ti hydrater tilhørende dette systemet funnet i naturen. Disse mineralene er sammenstillet i nedenstående tabell, hvori også er angitt hydratenes sammensetning og øvrige kjente data.

Okenit blev produsert i laboratoriet i lukkede hydrotermalbomber av SCHLÄPFER og NIGGLI[7] allerede i 1914. Forsøk i systemet $SiO_2—Al_2O_3—K_2O—CaO—H_2O$ ved 470° C resulterte i dannelse av dette hydrat. Undersøkelser av okenit dannet ved hydrotermalsynteser blev i 1938 foretatt av FLINT, MCMURDIE og WELLS[8]. CLARK og BUNN[9] påviste i 1940 at okenit forkommer i kjelsten. Okenit dannet på de ovenfor nevnte måter er identisk med naturlig okenit.

Gyrolit er først nevnt fremstillet av BAUR[10] i 1911 ved hydrotermalforsøk ved 450° C. KÖNIGSBERGER og MÜLLER[11] mente i 1918 å ha fremstillet en uren gyrolit under sine hydrotermal-forsøk. FLINT et al[8] fremstillet i 1938 hydratet ad hydrotermal vei, og MCMURDIE og FLINT[12] undersøkte i 1943 dets røntgenografiske egenskaper ved hjelp av pulverdiagrammer. Både disse siste studier og detaljerte undersøkelser av MACKAY og TAYLOR[13] av hydrotermalt fremstillede gyrolit enkeltkrystaller viser at gyrolit i naturen og gyrolit laget i laboratoriet er identiske.

I forbindelse med gyrolit finner man ofte nevnt truscotit, reyerit og centrallasit. Som fremhevet både av BESSEY[4] og av FLINT et al[8] er disse alle urene former av gyrolit.

Xonotlit kan uten vanskelighet fremstilles i laboratoriet. NAGAI[14,15,16,] beskrev i årene 1931—33 såvel xonotlit som afwillit og hillebrandit som alle var produsert i laboratoriet. Xonotlit blev fremstillet mellom 180° og 200° C. BUSSEM[17] foretok en inngående undersøkelse av NAGAI's hydrater, da der var tvil om deres identitet, og fastslo at xonotlit virkelig blev dannet. KÖHLER[18] fremstillet xonotlit av CaO og SiO_2 (kvarts eller amorft SiO_2) og vann i lukkede bomber. FORET[10] fant, ved å bruke CaO og kvarts i forholdet 1:1 i autoklav med vann, at xonotlit dannes mellom 140° C og 200° C. Ved lavere temperaturer blev det dannet et hydrat av omtrentlig sammensetning: $CaO \cdot SiO_2 \cdot 8H_2O$. Xonotlit er også laget i vannholdige oppløsninger (hvori $CaO/SiO_2 = 1$) av CLARK og BUNN[9] og av BESSEY[20] i temperaturintervallet 150 — 200° C, videre av JANDER og FRANKE[21] ved 300 — 350° C. FLINT et al[8] fremstillet xonotlit såvelsom gyrolit, foshagit og endel hydrater som ikke forekommer i naturen. Xonotlit blev under en rekke forsøk funnet å være stabil iallfall opp til 390° C.

HELLER og TAYLOR[35] fant ved forsøk i temperaturområdet 110—350° C at xonotlit er stabil over 160° C. Forsøk ved silikatforskningslaboratoriet med blandinger av $CaO/SiO_2 = 1$ resulterte i dannelse av wollastonit ned til 400° C ved 700 atm. Xonotlit er likeledes, under samme trykk, fremstillet i temperaturintervallet 220—390° C.

CLARK[3] fant under forsøk med xonotlitens oppløselighet under hydrotermalforhold at oppløsningens CaO/SiO_2 forhold varierte fra 0,40 ved 150° C til 0,24 ved 300° C. Ut fra disse forsøk konkluderte CLARK at en eller flere CaO rikere faser ble dannet.

Der har hersket endel uvisshet angående xonotlitens vanninnhold. NAGAI samt JANDER og FRANKE kom, basert på laboratorieundersøkelser, til det resultat at hydratet inneholder 0.2 mol H_2O, men antyder også den mulighet at vanninnholdet kan variere endel.

Xonotlit (og wollastonit) er påvist i kjelsten av CLARK og BUNN[9], av REINHARD, BRANDENBERG og OESTERHELD[22], av IMHOFF og BURKARDT[23], samt av ALCOCK og THURSTON[24]. De sistnevnte forskere fant også crestmoreit i kjelsten.

Crestmoreit har det hittil ikke lykkes å fremstille i laboratoriet. Det eksisterer også dissens angående dette hydrats vanninnhold. VIGFUSSON[25] samt FLINT et al[8] oppgir 3.0 mol, mens LARSEN og BERMAN[26] og BERMAN[27] mener at mineralet inneholder 4.0 mol H_2O. ALCOCK, CLARK og THURSTON[24] mener at naturlig forekommende crestmoreit er zeolitisk med et vanninnhold varierende mellom 0.5 og 1.5 mol. Navnet riversideit har undertiden vært anvendt på to mineraler, nemlig crestmoreit og foshagit. Ifølge TAYLOR[57] finner man ofte at mineraler som for eksempel i samlinger er kalt crestmoreit eller riversideit, i virkeligheten består av sub-mikroskopiske sammenvoksninger av tobermorit og wilkeit.

Foshagit blev fremstillet i laboratoriet i 1943 av VIGFUSSON, BATES og THORVALDSON[28] av en blanding av CaO og SiO_2-gel i forholdet 4:1 ved 170° C. Flint et al[8] produserte i 1938 foshagit fra silikarike blandinger ved temperaturer vel under 400° C.

Afwillit blev produsert i laboratoriet i 1929 av Thorvaldson og Shelton[29] ved temperaturer som varierte mellom 100° og 175° C og i 1932 ved 150° C av Nagai[15]. Bussem[17] påpekte at afwilliten og $2CaO \cdot SiO_2$ α-hydratet har svært like optiske egenskaper og fant ved hjelp av røntgen pulverdiagrammer at det siste blev produsert ved Nagai's forsøk, men utelukker derfor ikke den mulighet at afwillit også kunne forekomme.

Ved oppvarming taper afwilliten vann. Parry og Wright[55] viste at nesten alt vann kunne drives bort ved lengere tids oppvarming ved 1300° C. Videre undersøkelser utført av Moody[56] viser: $Ca_3(SiO_3OH)_2 \cdot 2H_2O \xrightarrow{550°C} 3H_2O + \gamma Ca_2SiO_4 + SiO_2 + CaO$ (γ Ca_2SiO_4 er lavtemperatur-formen med olivin struktur), videre: $Ca_3(SiO_3 \cdot OH)_2 \cdot 2H_2O \xrightarrow{1000°C} Ca_3Si_2O_7 + 3H_2O$ ($Ca_3Si_2O_7$ er rankinit). Differensial-termiske analyser av afwillit viser endoterm reaksjon (i atskillige trinn) i temperaturområdet 250—450° C. (Den mest merkbare reaksjon inntrer ved 370° C). Ved 820° C foregår en exoterm reaksjon. Det er liten tvil om at disse prosesser svarer til avspaltning av vann (250—450° C) og dannelse av rankinit (820° C).

Bessey[2] oppnådde ved 98° C, ved å behandle en $2CaO \cdot SiO_2$-gel med overskudd av H_2O, et produkt som ved røntgen pulverundersøkelser viste seg å bestå hovedsakelig av afwillit. (Det forekom noe $Ca(OH)_2$ og $CaCO_3$). Afwillitens røntgenografiske egenskaper blev først studert av Gottfried[30]. Imidlertid fastslo Megaw[31] etter preliminære undersøkelser av afwillitens struktur at Gottfried's resultater var feilaktige og publiserte i 1952 (Megaw[40]) de nærmere detaljer av sine studier. Av disse fremgår at den strukturelle formel for afwillit bør skrives $Ca_3(SiO_3\ OH)_2 \cdot 2H_2O$. Silika opptrer i isolerte tetraedre, men har OH grupper istedenfor O i noen hjørner. Kalsium-koordinasjonen er 6 eller 7 og de temmelig irregulære kalsium-polyedre deler kanter med hverandre og med tetraedrene i y-retningen. Vannstoff-båndene faller i to grupper med gjennomsnittlengder 2.52 Å og 2.72 Å. Gitterkonstantene i den monokline celle blev bestemt til a = 16.27 Å, b = 5.632 Å, c = 13.23 Å, β = 134°48'. Romgruppen er C_c, antall molekyler i cellen er 4. Sp.vekt kalkulert til 2.643±0.005.

Switzer og Bailey[32] har nylig foretatt en nøyaktig undersøkelse av en afwillit fra Crestmore, California, U.S.A. Egenskapene er såvidt kan sees identiske med laboratoriefremstillet afwillit's.

Hillebrandit finnes i litteraturen beskrevet fremstillet i laboratoriet for første gang i 1914 av Schläpfer og Niggli[7], som produserte mineralet ved 470° C av oppløsninger som inneholdt CaO, $CaCl_2$, SiO_2 og H_2O. Vigfusson[20] publiserte i 1931 resultater av røntgenundersøkelser av naturlig hillebrandit. Nagai[15] produserte hillebrandit ved 180° C av en blanding av CaO og SiO_2 i forholdet 3:1 i H_2O. Noe afwillit blev dannet samtidig. Vigfusson, Bates og Thorvaldson[28] mente å ha fremstillet hillebrandit ved 150—170° C. Det er imidlertid mulig at det rombiske hydratet disse forskere fant kan ha vært afwillit. Köhler[18] utførte i 1935 en rekke gode forsøk i systemet. Ved å varme 3 g. $2CaO \cdot SiO_2$ med 8—10 cc H_2O i 14 dager ved 212° C, eller 8 dager ved 290° C, oppnådde han et produkt som ble funnet å være hillebrandit. Dette mineral avgir sitt vann ved en temperatur noe over 300° C og går over til $2CaO \cdot SiO_2$ uten derved å endre krystallformen. Videre undersøkelser av laboratoriefremstillet hillebrandit ble utført av Keevil og Thorvaldson[33] i 1936. Disse konkluderte med at laboratorieproduktet ikke var identisk med naturlig hillebrandit. Senere undersøkelser ved hjelp av røntgenpulverdiagrammer har imidlertid vist at laboratorie-produktet er identisk med naturlig forekommende hillebrandit. Keevil og Thorvaldson[33] fant at hillebrandit er stabil ved 160° C.

Heller[58] studerte hillebrandit ved hjelp av røntgenstråler og fant en rombisk celle med a = 16.60 Å, b = 7.26 Å og c = 11.85 Å. Forutsatt at hillebrandit har en sp.vekt på 2.67, må enhetscellen inneholde 12 formel-enheter ($2CaO \cdot SiO_2 \cdot H_2O$).

Tidligere undersøkelser i $CaO—SiO_2—H_2O$ systemet av Taylor og Bessey[2], taylor[34] og Heller og taylor[35] har vist at en fase, av Taylor kalt hydrat (1) og av sammensetning $CaO \cdot SiO_2 \cdot nH_2O$ —$3CaO \cdot 2SiO_2 \cdot nH_2O$, eksisterer i systemet. Variasjon i sammensetning mellom de to grensene medfører ingen viktig endring i røntgendiagrammer. Dette hydrat (1) viste seg å være det endelige produkt av hydrotermalreaksjoner ved 110° C med CaO/SiO_2 forholdet 1/1. Det samme hydrat (1) ble senere laget også av Heller og Taylor[36] ved 180° C av utgangsprodukter hvor forholdet CaO : SiO_2 var 3:2.

Hydrat (1) er imidlertid ustabilt i slike blandinger når temperaturen overstiger 140° C. Det endelige og stabile produkt i intervallet 140—160° C er afwillit. I 180—200° C intervallet dannes xonotlit og hillebrandit. Undersøkelser utført av TAYLOR[37] av en lettvekt «sand-lime» blokk viste at hydrat (1) ble dannet metastabilt ved 183° C og utgjorde en vesentlig bestanddel av blokken. Hydrat (1) ble studert av McCONNELL[38] ved hjelp av røntgenstråler. Mineralene riversideit, tobermorit og plombierit ble påvist å tilsvare de tre hydrerings-stadier påvist i hydrat (1). CLARINGBULL og HEY[38] sammenlignet røntgendiagrammer av naturlig tobermorit med verdiene oppgitt av TAYLOR for hydrat (1) og fant at tobermorit var en bestandel av dette laboratoriefremstillede hydrat.

TAYLOR[60] har nylig ved hjelp av isobare dehydreringskurver og ved differensial-termiske analyser av hydrat av sammensetning $CaO \cdot SiO_2 \cdot nH_2O$—$1.5CaO \cdot SiO_2 \cdot nH_2O$ vist at der eksisterer tre distinkte hydrater med respektivt ca. 2.5, 1.0 og 0.5 mol. H_2O. Dette er i samsvar med McCONNELL's[38] resultater. Videre fant TAYLOR at H_2O innholdet er uavhengig av $CaO \cdot SiO_2$ forholdet, hvilket antyder at overskudd av Ca ikke finnes som $Ca(OH)_2$. Ved oppvarming til 800° C avgis alt vann og β-wollastonit dannes.

B. SYNTETISKE FORBINDELSER I SYSTEMET.

1. *Den silikarike del av systemet.*

De mest detaljerte studier i denne del av systemet blev foretatt av FLINT et al[8]. Deres eksperimenter foregikk i lukkede bomber hvor forholdet mellom fast substans og vann var 0.5 g til 10 ml. Temperaturen for forsøkene lå i intervallet 100—500° C. Forsøkstidene varierte fra 4 til 60 dager. Cristobalit blev dannet ved svært lave CaO innhold. Øking i CaO/SiO_2 forholdet resulterte ved temperaturer over 400° C i henholdsvis pseudowollastonit, wollastonit og β-$3CaO \cdot 2SiO_2$. Ved økning i CaO/SiO_2 forholdet oppnåddes under 400° C henholdsvis gyrolit, xonotlit (eller en udefinert $CaO \cdot SiO_2 \cdot H_2O$-forbindelse) og foshagit. Pseudowollastonit blev funnet å gå delvis over til wollastonit ved 500° C. Wollastonit er i 1948 fremstillet i laboratoriet av GILLINGHAM[43] ved 405° C. β-$3CaO \cdot 2SiO_2$ blev dannet ved hjelp av vann fra den mere almindelige α-$3CaO \cdot 2SiO_2$

form ved 500° C. α modifikasjonen blev vist å være metastabil. β modifikasjonen er stabil i luft ved temperaturer under 1024° C.

Dannelse av α-cristobalit av $CaO \cdot SiO_2$-gel med $CaO/SiO_2 = 0.67$ er observert også av JANDER og FRANKE[19] og foregår villig under hydrotermal-betingelser i SiO_2-rike blandinger i nøytrale eller svakt alkaliske oppløsninger. Dette er nylig demonstrert av WYART[41] med SiO_2 i vann og i vandig oppløsning av kaliumhydroksyd. TAYLOR[42] oppnådde det samme med SiO_2 i en vandig thaliumhydroksyd oppløsning.

Ved et høyere CaO/SiO_2 forhold enn under tidligere forsøk, men under ellers samme forsøksbetingelser, oppnådde JANDER og FRANKE[19] en forbindelse som blev antatt å være et $2CaO \cdot 3SiO_2$ hydrat. Røntgendata for dette hydrat viser god overensstemmelse med data som MCMURDIE og FLINT[11] senere publiserte for gyrolit. Den sterkeste linje i dette preparat passer ikke inn i gyrolit diagrammet, men faller nesten sammen med α-cristobalitens 4.16 Å linje. Det ligger nær å anta at JANDER og FRANKE fikk dannet gyrolit. Dette ville være i overensstemmelse med observasjoner i systemet utført av FLINT et al[8]. FORET[44] anvendte CaO og kvarts ved sine forsøk og fremstilte to forbindelser som ble kalt α og β hydrater av $CaO \cdot SiO_2$. α-hydratet blev dannet i temperaturområdet 100—140° C og β-hydratet mellom 140° og 200° C. TAYLOR[2] hadde anledning til å sammenligne FORET's upubliserte røntgendata med data som FLINT et al[8] gav for xonotlit og for et $CaO \cdot SiO_2$ hydrat. Det blev påvist at det siste hydrat var identisk med FORET's α-hydrat mens FORET's β-hydrat viste seg å være xonotlit. Røntgendiagrammer av α-hydratet (eller FLINT's hydrat) blev sammenlignet med publiserte diagrammer av riversideit og tobermorit med negativt resultat.

Forsøk på å bestemme vanninnholdet i $CaO \cdot SiO_2 \cdot nH_2O$ preparater dannet i temperaturområdet 130—290° C og tørket ved 100° C viste ifølge observasjoner utført av FORET[44], JANDER og FRANKE[19], og KÖHLER[17] et avtagende vanninnhold ved stigende dannelsestemperatur. Vi vet da også at en rekke distinkte hydrater med $CaO / SiO_2 = 1$ eksisterer (se tabell 1).

Ved forsøk hvor CaO / SiO_2 forholdet varierte mellom 1 og 2 fant JANDER og FRANKE at xonotlit eller hydrater av $2CaO \cdot SiO_2 \cdot nH_2O$ typen ble dannet alt eftersom temperaturen og $CaO—SiO_2$ forholdet varierte. Alle forsøk som varte over 8 dager resulterte imidlertid i dannelse av et $3CaO \cdot 2SiO_2$ hydrat som blev antatt å ha sammensetningen $3CaO \cdot 2SiO_2 \cdot H_2O$. Sammenligning av røntgendata for dette hydrat med data senere publisert av FLINT, MCMURDIE og WELLS[8, 12] viser at JANDER og FRANKES hydrat sannsynligvis var foshagit. NAGAI[14, 15, 16] rapporterte likeledes dannelsen av et $3CaO \cdot 2SiO_2$ hydrat, angivelig ved 150° C. Dette var muligens afwillit. BUSSEM[17] påpekte at afwillitens optiske egenskaper er nesten identiske med $2CaO \cdot SiO_2$ α-hydratets og røntgendiagrammer viser at dette hydrat blev dannet under NAGAI'S forsøk. Muligheten for at et $3CaO \cdot 2SiO_2$ hydrat kan dannes ved lav temperatur er fremdeles tilstede og videre undersøkelser bør foretas.

2. *Den CaO-rike del av systemet.*

Betingelsene for dannelse av hydrater av blandinger hvor $CaO/SiO_2 \geqq 2$ viser seg å være enda mere uklart definerte enn for CaO fattigere blandinger. Det synes mulig at en varietet av metastabile produkter kan dannes under forskjellige forhold, men det er også mulig at hvert av produktene har et stabilitetsområde hvis grenser er bestemt av blandingens sammensetning, av temperaturen og tildels også av trykkforholdene.

Vi skal se litt nærmere på endel av disse forbindelsene:

$3CaO \cdot SiO_2 \cdot 2H_2O$. Dette produkt er blitt laget av BESSEY[45], KEEVIL og THORVALDSON[33] og av FLINT et al[8] av $3CaO \cdot SiO_2$ i temperaturområdet 150—500° C. Ved lavere temperaturer inntrer hydrolyse så $2CaO \cdot SiO_2$ α-hydrat dannes. FLINT et al[8] laget også $3CaO \cdot SiO_2 \cdot 2H_2O$ av $3CaO \cdot SiO_2$ når ekstra CaO var tilstede og av vannholdige blandinger med $CaO / SiO_2 = 3\text{-}4$ ved 275° C eller høyere temperatur.

Vanninnholdet blev av KEEVIL og THORVALDSON[33] bestemt til 1.3-1.9 mol., og av FLINT et al[8] til 1.6-2.0 mol. BESSEY[46, 47] fant 1.5-2.0 mol. og antydet at den korrekte formelen for hydratet er $3CaO \cdot SiO_2 \cdot 2H_2O$, men at 0.5 mol. av vannet er løsere knyttet i forbindelsen enn det øvrige vann. [Han antyder også at hydratet muligens har norbergit-struktur ($Mg_3SiO_4(OH,F)_2$).] Mesteparten av vannet derimot er fast knyttet til strukturen og drives ikke av før ved ca. 900° C. Ved denne temperatur spaltes hydratet til $2CaO \cdot SiO_2$, CaO og H_2O damp. Dette hydrat er relativt stabilt ved lave temperaturer (20—100° C), selv rysting med vann i flere måneder resulterte ikke i noen endring i de karakteristiske røntgenlinjer (TAYLOR og BESSEY[2], BESSEY[4]).

$2CaO \cdot SiO_2 \cdot (1—1.25)H_2O$ α-hydrat. Denne forbindelse blev først påvist av THORVALDSON og SHELTON[29] i damptørket Portland sement-mørtel. Dannelsen blev ment å skyldes dels hydrering og hydrolyse av sementens bestandeler, dels reaksjoner mellom CaO frigjort fra sementen og SiO_2 fra sanden. Senere er den samme forbindelsen studert av VIGFUSSON et al[28], BESSEY[4], NAGAI[14, 15, 16] og FLINT et al[8]. I hvert tilfelle blev hydratet syntetisert av et utgangsmateriale bestående av CaO med SiO_2-gel eller kvarts, eller i vannrike blandinger med $CaO/SiO_2 = 2$. Temperaturen var nesten alltid ca. 200° C. VIGFUSSON et al[28] produserte krystaller på 0.5—1.5 mm av dette hydrat ved 170° C ved å la mettet CaO-vann reagere med plater av kvarts eller silika-glass i autoklav. HELLER og TAYLOR[61] har vist ved eksperimenter at α-hydratet er stabilt opptil 140° C.

Vanninnholdet er ikke kjent med sikkerhet. FLINT et al[8] oppgir formelen for forbindelsen til å være $10CaO \cdot 5SiO_2 \cdot 6H_2O$ (eller om man vil $2CaO \cdot SiO_2 \cdot 1.2H_2O$). BESSEY fant vanninnholdet til å variere mellom 1.1 og 1.25 mol. Dette hydrat taper litt vann i luft ved 450° C, men taper, ifølge THORVALDSON[48] og VIGFUSSON et al[28], alt vann og går over til β $2CaO \cdot SiO_2$ først ved 900° C.

HELLER[57] fremstilte α-hydratet ad hydrotermal vei fra β-hydratet, og fant at den sannsynlige formel var: $2CaO \cdot SiO_2 \cdot H_2O$. Hydratet er rombisk: $a = 9.34$ Å, $b = 9.22$ Å, $c = 10.61$ Å. Sp.vekt $= 2.76$ gir $z = 8$, romgruppen er $P_{2, 2, 2}$. Strukturformelen bør skrives $Ca_2(SiO_3 \cdot OH)OH$ siden diskrete $(SiO_3 \cdot OH)^{3-}$tetraedere er påvist. Alt vann blev funnet å avgis ved 500° C. Pulveret som blev igjen blev etter avkjøling funnet å bestå av $\gamma \cdot 2CaO \cdot SiO_2$.

$2CaO \cdot SiO_2 \cdot H_2O$ β-hydrat. SCHLÄPFER og NIGGLI[7] påberopte seg i 1914 å ha fremstillet hillebrandit ved 470° C. Senere oppnådde en rekke forskere en forbindelse som lignet svært på hillebrandit, men som blev betegnet $2CaO \cdot SiO_2$ β-hydrat. Disse forsøk skjedde i temperaturområdet 150°—250° C. Det er mange små forskjeller mellom røntgendiagrammer av hillebrandit fra naturen og av laboratoriefremstillet $2CaO \cdot SiO_2$ β-hydrat, men disse skriver seg fra fremmede elementer som finnes i fast oppløsning i naturlig hillebrandit. Det må ifølge TAYLOR og BESSEY[2] ansees som sikkert at $2CaO \cdot SiO_2$

β-hydratet er identisk med hillebrandit. HELLER og TAYLOR[61] har funnet dette hydrats stabilitetsområde å ligge mellom 140° og 180° C.

$2CaO \cdot SiO_2 \cdot (0.3—1.0)H_2O$ γ-hydrat. Dette hydrat blev laget av KEEVIL og THORVALDSON[33] samt av FLINT et al[8] av både β- og γ-$2CaO \cdot SiO_2$ ved høyere temperaturer enn anvendt ved fremstillingen av α- og β-hydratene. Produktet er oftest blandet med andre hydrater, men røntgendataene viser i alle tilfelle store likheter.

KEEVIL og THORVALDSON[33] mente at γ-hydratet var det mest almindelige produkt over 170° C, BESSEY fremstillet det ved 190° C, men FLINT et al[8] fant α-hydratet stabilt ved 200° C og γ-hydratet ved 250° C og høyere temperaturer. JANDER og FRANKE[19] oppnådde γ-hydratet ved 300°—350° C når de brukte $CaO \cdot SiO_2$-geler hvor $CaO/SiO_2 \geqq 2$. HELLER og TAYLOR[61] fant at dette hydrat er stabilt ved temperaturer over 180° C. Litteraturen viser god overensstemmelse angående stabilitetsområdet for dette hydrat.

Vanninnholdet av γ-hydratet ble funnet av KEEVIL og THORVALDSON[33] å kunne variere mellom 0.3 og 1.0 mol. uten å medføre noen forandring i røntgenlinjene. Den gjennomsnittlige lysbrytningsindeks varierte fra 1.64 til 1.62. TAYLOR og BESSEY[2] observerte en lignende funksjon hvorved en variasjon i vanninnholdet fra 0.4—0.5 mol. resulterte i en endring i lysbrytningen fra 1.635 til 1.625.

$2CaO \cdot SiO_2(0.67)H_2O$ δ-hydrat. FLINT et al[8] mener å ha produsert dette av $2CaO \cdot SiO_2$ α-hydrat ved 450° C. Inngående undersøkelser er nødvendige for å bringe på det rene om dette er en fase adskilt fra δ-hydratet. De hittil kjente syntetiske forbindelser i systemet er sammenstillet i tabell 2 sammen med en rekke andre data for disse hydratene.

Reaksjoner ved 100 °C eller ved Lavere Temperaturer.

Undersøkelser av de reaksjoner som foregår ved temperaturer under 100C° er av tidligere anførte grunner svært vanskelige å gjennomføre. STEINOUR[49] har gitt en oversikt over det utstrakte arbeide som er utført i dette temperaturområdet. Den eneste forbindelse med et bestemt CaO/SiO_2 forhold er et monokalsium-silikat-hydrat $CaO \cdot SiO_2 \cdot nH_2O$ (FLINT og WELLS[50]). Ved økning av CaO/SiO_2 forholdet er påvist et område med en kontinuerlig fast oppløsning mellom $CaO \cdot SiO_2 \cdot nH_2O$ og et $3CaO \cdot 2SiO_2$ hydrat. Selv om denne fase

Tabell 2.

SYNTETISKE FORBINDELSER I SYSTEMET

Sammensetning	Krystallform	Lysbrytning			Spesifikk vekt	Andre egenskaper
		α	β	γ		
$3CaO \cdot SiO_2 \cdot 2H_2O$	nålformet	1.589 -1.590	— —	1.589 -1.602	2.56	
$2CaO \cdot SiO_2 \cdot (1—1.25)H_2O$ α-hydrat	rombiske prismer	1.614	1.621	1.635	2.59—2.80	bi-aksial +, 2V= 68°
$2CaO \cdot SiO_2 \cdot H_2O$ β-hydrat	nål- eller fiberformet	1.597—1.600			2.58	(hillebrandit) ?
$2CaO \cdot SiO_2(0.3—1.0)H_2O$ γ-hydrat	finkrystallinsk materiale	1.62—1.64			2.67	
$2CaO \cdot SiO_2(0.67)H_2O$ (δ-hydrat)	pseudomorf av $2CaO \cdot SiO_2$ α-hydrat	1.642—1.672			—	
$CaO \cdot SiO_2 \cdot H_2O$	finkrystallinsk materiale (stenglig)	1.603			—	(Flint's hydrat)
$4Ca \cdot O5SiO_2 \cdot 5H_2O$	nålformet	1.54			—	
$4CaO \cdot 5SiO_2 \cdot 12H_2O$	—	—			—	(Bessey's hydrat, muligens metastabilt)
$6CaO \cdot 4SiO_2 \cdot 3H_2O$	—	—			—	(Flint et al)

i likevekt med kalsium-hydroksyd-oppløsninger ved romtemperatur ofte, på grunnlag av undersøkelser med mikroskop, er beskrevet som amorf, har en rekke forskere oppnådd gode røntgendiagrammer som viser at fasen er krystallinsk. De tidligere data for denne fasen finnes summert i en publikasjon av FORSEN[51]. Data i tillegg til disse er oppnådd av TAYLOR og BESSEY[2], samt BROCARD[52]. Røntgen «spacings» viser seg, ifølge disse forskere, å være uavhengig av CaO/SiO_2 forholdet når dette varierer mellom grensene 1.0 og 1.5 og viser også som påpekt av FORET[44] en likhet med «spacing» forholdene hos $CaO \cdot SiO_2 \cdot H_2O$ forbindelsen. Det er derfor mulig at forbindelsen som er stabil ved romtemperatur er strukturelt lik den sistnevnte. Videre undersøkelser av dette forhold foretas for tiden av TAYLOR.

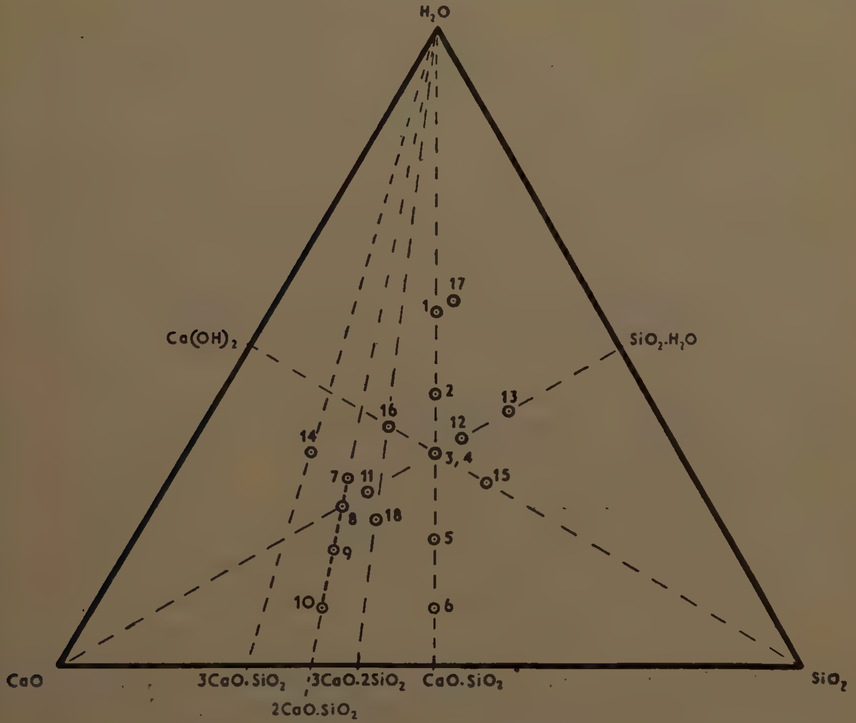
BESSEY[4] og FORSEN[53] fant et $2CaO \cdot SiO_2$ hydrat å være stabilt i mettede eller nær mettede CaO oppløsninger ved romtemperatur. Det er mulig at dette hydrat er identisk med $2CaO \cdot SiO_2$ α-hydratet. (BESSEY og TAYLOR[2]).

FLINT et al[8] nevner at en forbindelse av sammensetning $6CaO \cdot 4SiO_2 \cdot 3H_2O$ blev dannet når β-$2CaO \cdot SiO_2$ med overskudd av vann fikk stå ved romtemperatur i 10 år. (Den samme forbindelse blev oppnådd ved 175° C av $2CaO \cdot SiO_2$ glass som inneholdt 12 % B_2O_3). Hydratet viste et distinkt røntgendiagram forskjellig fra afwillitens. BESSEY oppnådde derimot afwillit ved 98° C ved å behandle en $2CaO \cdot SiO_2$-gel med overskudd av vann.

FLINT og WELLS[50] mente, utfra studier av oppløselighetskurver, at et $CaO \cdot 2SiO_2$-hydrat måtte dannes når CaO/SiO_2 forholdet er vesentlig mindre enn 1. ROLLER og ERVIN[54] sluttet fra studier av faselikevekter og fysikalskkjemiske betraktninger at et $3CaO \cdot 4SiO_2$ hydrat kunne dannes. BESSEY fremstilte en forbindelse av sammensetningen $4CaO \cdot 5SiO_2 \cdot 12H_2O$ ved felling i en oppløsning av natriumsilikat og kalsium-klorid, men det er mulig at denne forbindelse er metastabil.

Sammenstilling av Resultatene.

Alle hittil kjente hydrater i CaO—SiO_2—H_2O systemet finnes i trekantdiagrammet i figur 1. Tiltross for den store mengde publikasjoner som behandler systemets hydrater, vites svært lite om de

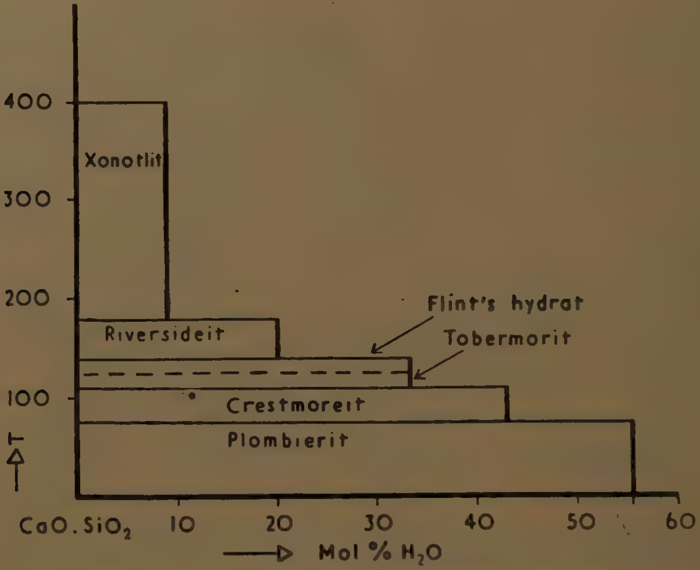


Figur 1. $CaO—SiO_2—H_2O$ systemets hydrater.

1. Plombierit. 2. Crestmoreit. 3. Tobermoreit. 4. Flint's hydrat. 5. Riversideit. 6. Xonotlit. 7—8. $2CaO \cdot SiO_2$—α hydrat. 8. $2CaO \cdot SiO_2$—β hydrat (hillebrandit). 8—9. $2CaO \cdot SiO_2$—γ hydrat (I). 9. $2CaO \cdot SiO_2$—δ hydrat. 9—10. $2CaO \cdot SiO_2$—γ hydrat (II). 11. Foshagit. 12. $4CaO \cdot 5SiO_2 \cdot 5H_2O$. 13. Okenit. 14. $3CaO \cdot SiO_2 \cdot 2H_2O$. 15. Gyrolit. 16. Afwillit. 17. $4CaO \cdot 5SiO_2 \cdot 12H_2O$ (muligens metastabil). 18. $6CaO \cdot 4SiO_2 \cdot 3H_2O$.

enkelte forbindelsers stabilititetsområder. Fast-fase oppløsninger forekommer i svært liten utstrekning. Bare mellom hydratene av sammensetning $CaO \cdot SiO_2 \cdot nH_2O$ og $3CaO \cdot 2SiO_2 \cdot nH_2O$ vet man at det eksisterer en viss oppløselighet i fast fase. Disse oppløselighetsforhold, spesielt ved temperaturer under 100° C, bør undersøkes i laboratoriet.

Forholdene i det binære system $CaO \cdot SiO_2 - H_2O$ er fremstillet i figur 2. Dette preliminære diagram er oppstillet som et resultat av litteratur-studier og en rekke eksperimenter utført ved dette labo-



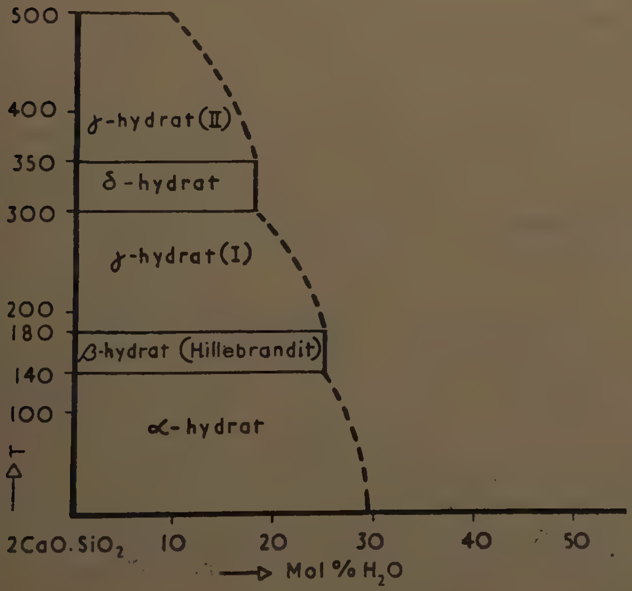
Figur 2. $CaO \cdot SiO_2$—H_2O systemets hydrater.

ratorium. De angitte temperaturer er, unntatt for xonotlit, omtrentlige. Som det sees er overgangene mellom hydratene skarpe. Bare for crestmoreitens vedkommende er der indikasjoner som synes å antyde at vanninnholdet til en viss grad avtar med stigende temperatur.

Hydratene i $2CaO \cdot SiO_2$—H_2O systemet oppfører seg ganske anderledes. Således avtar α-hydratets vanninnhold fra 1.25—1.0 mol. ved oppvarming til ca. 140° C. I temperaturområdet 140—180° C synes β-hydratet å være stabilt. Såvidt det har vært mulig å kontrollere er dette hydrat identisk med hillebrandit. Over 180° C opp til ca. 300° C eksisterer et γ-hydrat. Dette avgir vann ved oppvarming. Forsøk ved 325° C produserte et hydrat som i pulverdiagrammer viser store likheter med et δ-hydrat fremstillet av McMurdie og Flint[12]. Røntgen-pulverdiagrammene for dette er på vesentlige punkter forskjellig fra γ-hydratets. Det er derfor meget sannsynlig at δ-hydratet eksisterer som en selvstendig forbindelse stabil mellom ca. 300° og 350° C. Videre forsøk ved 450° C frembragte et produkt som viser likheter med det tidligere nevnte γ-hydrat, men som ikke kan sies å være identisk med dette. Disse forsøk tyder på at der i dette binære system eksisterer et hydrat som ved ca. 180° C inneholder 1.0 mol. vann, men som ved oppvarming vil avgi vann gradvis og ved ca. 300° C gå over til et distinkt δ-hydrat som ikke avgir vann.

Ved ca. 350° C er ikke δ-hydratet lenger stabilt, men går over til et nytt hydrat som har evnen til å avgi vann. Vanninnholdet i dette siste hydrat er 2/3 mol. ved ca. 350° C men synker til 0.3 mol. ved ca. 500° C. Hydratene $2CaO \cdot SiO_2 \cdot (2/3—1)H_2O$ og $2CaO \cdot SiO_2(0.3—2/3) \cdot H_2O$ har i litteraturen gått under fellesbetegnelsen γ-hydrat. For å skjelne mellom dem og samtidig ikke skape forvirring, kan det være fornuftig å betegne dem henholdsvis hydrat γ (I) og γ (II), som gjort i figur 3.

Hydrater hvor $CaO/SiO_2 = 2$ vil som nevnt ofte jevnt avgi sitt vanninnhold ved økende temperatur og viser derved en likhet med visse leirmineraler, som for eksempel montmorrillonit. Hydrater hvor $CaO/SiO_2 = 1$ viser derimot liten evne til å avgi vann ved økende temperatur. Disse forhold bør nærmere belyses blant annet ved røntgenundersøkelser av enkelt-krystaller av hydrater fra både $CaO \cdot SiO_2—H_2O$ og $2CaO \cdot SiO_2—H_2O$ systemet, såvelsom av intermediære forbindelser.



Figur 3.
$2CaO \cdot SiO_2—H_2O$ systemets hydrater.

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NORSK GEOLOGISK TIDSSKRIFT 33

KJEMISKE BINDINGER I SILIKATER, ET SVAR.

AV

HANS RAMBERG

Når man behandler kjemiske bindinger som vesentlig er av jonisk karakter, er det ofte meget vanskelig å skille mellom gjensidig polarisering av nabojoner og kovalent binding mellom disse. Enkelte forskere innen teoretisk kjemi foretrekker å snakke om resonans mellom jonisk og kovalent binding (L. PAULING, Y. K. SYRKIN og M. A. DYATKINA, etc.), mens andre forskere snakker om polariserte joner. A. V. van ARKEL har for eksempel forfattet en meget instruktiv og samtidig enkel lærebok i uorganisk kjemi, hvor hovedtrekkene ved krystallers og molekylers stabilitetsforhold betraktes ut fra joneteorier (van ARKEL, 1949). W. WEYL har gått særlig vidt i retningen av å anvende jonesynspunkt på kjemiske forbindelser, idet han til og med betrakter diamant som bestående av C^{4-} joner som er sterkt polarisert av C^{4+} joner. Dette må sies å være en temmelig vidtgående slutning, men samtidig later det til at Pauling og hans skole ofte fører resonansbegrepet vel langt over mot den joniske side av bindingsskalaen. Det er således delte meninger blant spesialistene angående problemet polarisasjon kontra kovalent-jonisk resonans.

Den kjemiske bindingsteoris betydning for geologien ligger vesentlig i dens potentielle evne til å forutsi og tyde mineralenes stabilitetsforhold og elementfordelingen mellom dem. Det er derfor uheldig for geologer og geokjemikere at teoriene for de kjemiske bindinger ennu er vaklende og divergerende. Imidlertid viser det seg heldigvis at man kan nå fram til kvalitativt lignende stabilitetsforhold for mange mineralreaksjoner uavhengig av hvorvidt man betrakter bindingene som mer eller mindre polariserte joniske bånd eller som resonansfenomener mellom jonisk og kovalente tilstander. Forfatteren har for eksempel i flere arbeider anvendt begge synspunkter for å forklare elementfordelingen mellom koeksisterende mineraler (H. R. 1952 a, 1953, 1954). I den første avhandling ble metallfordelingen mellom forskjellige typer silikater behandlet, og under disse forhold ble det funnet formålstjenlig å tyde observasjonene i lys av Paulings resonansprinsipp hvor elementenes elektronegativitet spiller en framtredende rolle. Denne metode ble anvendt vesentlig fordi forfatteren på dette tidspunkt ikke kjente noen skikket indikator for den relative polariserende evne for katjoner med ulik elektronkonfigurasjon, for eksempel edel-gass katjoner kontra 18-elektron katjoner eller overgangsmetall joner etc.[1] Verdien av denne betraktningsmåte settes imidlertid under tvil av H. FLOOD (1953), som etter oppfordring imøtegår forfatterens arbeide av 1952 (a) og foretrekker å behandle fordelingen av Fe og Mg i silikater (hovedtemaet i den omdiskuterte avhandling) som resultat av polarisasjon av surstoffjonet. En slik tolkning er selvsagt helt brukbar og til og med enklere enn den Paulingske tydning av resonans mellom jonisk og kovalent binding. I denne forbindelse må nevnes at forfatteren har funnet polarisasjonsbetraktninger mer fordelaktig i senere arbeider over silikatenes stabilitetsforhold, (H. R. 1953, 1954). Krystallenergetiske forhold ved oksysalter med edel-gass joner ble forøvrig diskutert ut fra rent jonisk synspunkt i en tidligere artikkel (H. R. 1952 b).

Floods innlegg er imidlertid ikke egnet til å gi klarhet i de problemer som diskuteres, idet han beklageligvis opererer med helt forkjærte varmetoninger for et par av de reaksjoner som fremlegges som eksempler. Det er også uheldig at Floods innlegg kunne gi inntrykk av at kovalente bindinger er av helt underordnet betydning i silikatkjemien. Dette er langt fra et akseptert syn blant strukturkjemikerne, noe som inspeksjon av A. F. WELLS' utmerkete bok av 1950 gir tydelig inntrykk av. Den viktige Si—O binding i silikater er for eksempel antatt å ha en dominerende kovalent karakter, likeledes er H—O bindingen i hydroksylholdige silikater av utpreget kovalent type. Man må videre anta at bindingene mellom tungmetaller og surstoft i silikater har en betydelig tilblanding av kovalente krefter, noe som er tilfelle i for eksempel Zn_2SiO_4 hvor Zn^{2+} er firekoordinert.

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[1] Senere har det imidlertid vist seg at joniseringspotentialet er en meget tilfredstillende indikator på katjoners polariserende evne; (L. H. AHRENS 1952, H. RAMBERG 1953.)

Flood fremhever i sitt innlegg at begrepet resonans mellom jonisk og kovalent binding fører til meget uriktige resultater dersom det anvendes på reaksjoner mellom typiske joniske krystallforbindelser som for eksempel halider og oksyder av alkali- og jordalkali metallene. Dette er selvsagt helt korrekt, idet det her er de velkjente regler for relative joneradier og joneladninger som bestemmer reaksjonenes eksoterme retning. En hel del av disse regler er forøvrig av stor betydning for geokjemikeren og er av den grunn blitt sammenfattet og anvendt i forfatterens siterte arbeide av 1953. Ved å trekke slike reaksjoner inn i diskusjonen forlater imidlertid Flood det område som den omdiskuterte artikkel omfatter. Her er det tale om komplekse surstofforbindelser, nemlig silikater og andre oksysalter samt hydroksyder. Bare i et enkelt tilfelle er et sulfid tatt med i reaksjonsforløpet.

Basert på kalorimetriske data slutter forfatteren i sin artikkel at baseutvekslingsreaksjoner mellom oksysalt-par går eksotermt mot salter av sterk syre og sterk base (mest elektropositive metalls oksyd) samt salter av svak syre og svak base. Det anvendte materiale omfatter kun oksysalter og hydroksyder, og slutningen gjelder således også bare disse stoffer. Selv under den forutsetning advarer forfatteren mot unntagelser: «We certainly cannot expect the principle discussed to be without exceptions.— — see for example the nitrates and sulfates in fig. 2.» (H. R. 1952). Det virker merkelig i lys av dette at Flood som kritikk mot forfatterens slutning for oksysalter viser til reaksjoner som omfatter alkalihalider, stoffer som overhodet ikke berøres i forfatterens artikkel. På tross av at Flood blander inn uvedkommende reaksjoner har det ikke lykkes ham å finne særlig overbevisende eksempler som viser at forfatterens «regel har høyst tvilsom verdi som generell sats».

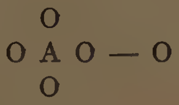
De to eksempler som oppgis, nemlig:

$$2\ LiCl + Cs_2CO_3 = Li_2CO_3 + 2\ CsCl, \text{ og}$$
$$LiCl + KF = KCl + LiF$$

er ikke endoterme (med positiv ΔH-verdi) som Flood påstår, men i høy grad eksoterme, noe som selv en overfladisk inspeksjon av reaksjonen viser på basis av velkjente stabilitetslover for joneforbindelser, selv om Flood finner at «Årsaken til dette (nemlig at reaksjonene har de forkjærte positive varmetoninger!) ikke er vanskelig å se». Data fra KUBASCHEWSKI og EVANS, 1951, gir varmetoningene henholdsvis ca.—33 og ca.—17 kcal. for de to reaksjoner, mens Flood oppgir + 25 og + 17 kcal. Reaksjonene går således eksotermt mot salt av svak syre og svak base samt salt av sterk syre og sterk base, og er i full overensstemmelse med forfatterens slutning for oksysalter.

I den omdiskuterte artikkel berøres oksysyrenes relative styrke, da dette har betydning for de forskjellige silikaters evne til å skille mellom ulike katjoner. Det påvises at styrken av flere oksysyrer tiltar med tiltagende jonisk karakter av H—O båndet, idet økende jonisk karakter i disse tilfeller svekker bindingen mellom proton og surstoff. Flood mener tilsynelatende at dette er en utilfredsstillende forklaring og holder på den «gamle og velkjente» joniske teori for å forklare oksysyrenes styrke. Begge betraktningsmåter fører til samme kvalitative resultat, men det kan synes kunstig å postulere sentraljoner av usannsynlig høy ladning (Cl^{7+}, S^{6+} etc.) når det later til å være temmelig stor enighet om at oksyjonene vesentlig er holdt sammen ved kovalente krefter. (Se for eksempel WELLS, 1950 s. 343 ff. og PAULING, 1948, s. 239 ff.) Forfatteren omtaler utelukkende oksysyrer og slutningen kan ikke overføres direkte på andre syrer, slik kritikken gjør når det fremheves at styrkeforholdet mellom HF, HCl, HBr, HJ etc.ikke er i overensstemmelse med forfatterens slutning. Det kan likevel være av interesse å betrakte forholdet litt nøyere. I de sistnevnte syrer tiltar styrken generelt med avtagende jonisk bindingskarakter av båndet H-syrerest. Årsaken til denne forskjell mellom oksysyrenes relative styrke og halogenvannstoff syrenes relative styrke kan selvsagt lett forklares ved jonisk bindingsteori. Forholdene kan imidlertid også bringes i overensstemmelse med elektronegativitetsteorien uten at forfatteren dermed påstår at den siste er den mest riktige. Men man må da erindre at den totale bindingsenergi for båndene H—F, H—Cl, H—Br etc. ikke står i noe enkelt forhold til elektronegativitets-forskjellen mellom de to ulike atomer. Etter Paulings syn er det bare forskjellen, Δ, mellom energien av en binding A—B og middelenergien av bindingene

A—A og B—B som alminneligvis stiger med stigende X-forskjell mellom A og B (X = elektronegativitet). Ser man på bindingsenergiene i HF, HCl, HBr, HJ etc. så avtar Δ-verdien for disse fra H—F til H—J på grunn av avtagende X-forskjell. Videre avtar også båndstyrken mellom like halogenatomer fra F_2 til J_2 vesentlig på grunn av størrelsen av atomradiene. Resultatet må følgelig bli at den totale båndstyrke avtar fra H—F til H—J, og at den joniske dissosiasjonstendens tiltar i denne rekkefølge (dersom den relative elektron-affinitet av halogenatomene ikke motvirker dette). For oksysyrer derimot blir forholdet helt anderledes, idet her varierer Δ-verdien for H—O båndet og dets totale bindingsenergi i motsatte retninger, noe som kan være egnet til å skape forvirring. Her er vannstoff alltid bundet til ett og samme atom, nemlig surstoff hvis radius er temmelig konstant fra den ene oksysyre til den annen. I overensstemmelse med Paulings teori finnes Δ-verdien av H—O båndet i oksysyrene når man sammenligner dette med et H—H bånd og et O—O bånd. Dette siste må man tenke seg tilveiebrakt ved at et ekstra surstoffatom er bundet til et av oksyjonets surstoff på følgende vis:



$$\begin{array}{ccccc} & \mathrm{O} & & & \\ \mathrm{O} & \mathrm{A} & \mathrm{O} & — & \mathrm{O} \\ & \mathrm{O} & & & \end{array}$$

(sammenlign per-syrer).

Spørsmålet blir nu hvorledes denne O—O binding varierer i styrke når polariserbarheten av surstoffet (eller dets elektronegativitet) i oksyjonen varierer fra syre til syre? Det er grunn til å anta at styrken av O—O båndet øker når oksyjonets surstoff blir mer og mer polariserbart, (eller mindre elektronegativt) og syrestyrken generelt avtar.[1] Den totale båndstyrken mellom H og O kan følgelig

---

[1] Dette er for eksempel tilfelle for O—O båndet i peroksyder av alkali- og jordalkali metallene, noe som kan sannsynliggjøres av følgende reaksjonsvarmer:

MgO	+ ½ O_2	= MgO_2	— 5.05 kcal.
—143.85	0	—148.9	
CaO	+ ½ O_2	= CaO_2	— 5.6 -
—151.9	0	—157.5	

Note forts.

også meget vel øke med avtagende syrestyrke selv om Δ-verdien for H—O båndet synker med avtagende syrestyrke.

Disse betraktninger viser at de her omtalte syrers styrkeforhold kvalitativt meget vel kan forenes med Paulings elektronegativitetsprinsipp.

Det vesentlige i Floods innlegg knytter seg til forfatterens tolkning av Fe—Mg fordelingen mellom basiske (orto) og sure (meta) silikater. I den omdiskuterte artikkel viser forfatteren ved tallrike data at følgende reaksjon er drevet mot høyre (ved lav temperatur):

$$2\,FeSiO_3 + Mg_2SiO_4 = 2\,MgSiO_3 + Fe_2SiO_4$$

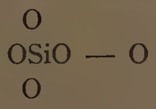
Dersom man betrakter reaksjonen ut fra begrepet polarisasjon og kontrapolarisasjon så kan den sees som en følge av den sterke binding mellom det sterkt polariserende Fe^{2+} og det sterkt polariserbare ortosurstoffjon. Nu påstår Flood at «Rambergs betraktninger er egnet til å gi det stikk motsatte inntrykk — at det er Mg-jonets tendens til å binde pyro- eller meta-surstoffjonet som er avgjørende». Saken er imidlertid den at forfatteren ikke forsøkte å forklare hvilke

Note forts.

SrO	+	½ O_2	=	SrO_2	— 12.5	kcal.
—141.1		0		—153.6		
BaO	+	½ O_2	=	BaO_2	— 17.1	-
—133.4		0		—150.5		
Li_2O	+	½ O_2	=	Li_2O_2	— 9.3	-
—142.4		0		—151.7		
Na_2O	+	½ O_2	=	Na_2O_2	— 21.2	-
—99.4		0		—120.6		
K_2O	+	½ O_2	=	K_2O_2	— 31.6	-
—86.4		0		—118.0		
Rb_2O	+	½ O_2	=	Rb_2O_2	— 22.8	-
—78.9		0		—101.7		
Cs_2O	+	½ O_2	=	Cs_2O_2	— 20.3	-
—75.9		0		—96.2		

Bortsett fra reaksjonene med rubidium- og cesiumoksyder, ser man at energiutviklingen ved dannelsen av peroksyder øker med katjonene økende radius og avtagende polarisasjonskraft. Selvsagt skylles dette ikke bare O—O båndets styrke, men også gitterenergien av monoksydene som avtar numerisk med økende joneradius og således vil virke på reaksjonsforløpet i samme retning som styrken av O—O båndet. At O—O båndet influeres av omliggende joners polariserende evne framkommer også av varierende O—O avstanden. I H_2O_2 er den 1.46 ± 0.03 Å, i SrO_2 1.35 og i BaO_2 1.29 (Wells, 1950 s. 325).

krefter som driver reaksjonen, men utelukkende demonstrerte ved mineralogiske data at Fe viser en tendens til å binde seg med hva forfatteren kalte det minst elektronegative surstoffjon i silikater, mens Mg viser tendens til å knyttes til det mer elektronegative surstoffjon, samt at dette stort sett var hva man kunne vente på bakgrunn av mange andre oksysalters oppførsel. Det inntrykk Flood har fått angående årsaken til reaksjonen ovenfor skriver seg derfor tilsynelatende mindre fra forfatterens artikkel enn fra Floods eget billede av elektronegativitetsprinsippet. Dersom man benytter begrepgrepet resonans mellom jonisk og kovalent binding vil reaksjonen få sin naturlige forklaring i og med at bindingen mellom Fe og ortosurstoff er mest kovalent og således også i disse tilfeller særlig sterk. Denne betraktning kommer ikke på noen måte i«direkte konflikt med de gitterenergetiske betraktninger». Det er mulig at Floods inntrykk skriver seg fra en sammenblanding av Δ-verdiene (*additional ionic resonance energy*) og den Coulumbske energi mellom metall- og surstoffioner i silikatene. Ifølge Pauling burde Δ-verdien være størst i den mest joniske Mg—O_{meta} binding, og minst i det mest kovalente Fe—O_{otro} bånd. Dette forhindrer imidlertid ikke at den Coulumbske energi for Fe^{2+}—O_{2-} er numerisk større enn for Mg^{2+}—O_{2-} idet man erindrer at det tenkte sammenlignings O—O-bånd i konfigurasjonen:



$$\begin{array}{l} O \\ OSiO — O \\ O \end{array}$$

er noe sterkere i ortosilikatet enn i metasilikatet. Videre er fordampningsvarmen større for jern enn magnesium, noe som viser at båndet mellom jernatomer er sterkere enn mellom magnesiumatomer; dessuten er det annet joniseringspotensial størst for jernatomet. Alle disse ting tillater Δ-verdien for Mg—O_{meta} å være større enn for Fe—O_{orto} på tross av at det motsatte er tilfelle med de Coulumbske energier mellom metall- og surstoffjoner.

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[1] Det taes for gitt at dette er en trykkfeil for elektronegativitetsskalaen.

Manuskript mottatt 16. november 1953.

NOTISER

Beriktigelse.

I mine bemerkninger angående verdien av elektronegativitetsskalaen i diskusjonen av bindingsenergien i silikatstrukturer (dette tidsskrift s. 162—67, Bd. 32), er jeg dessverre kommet i skade or åf begå et par villedende hastverksfeil.

At der i tittelen står elektronøytralitetsskalaen istedenfor elektronegativitetsskalaen, har forhåpentligvis ikke gitt grunn til forvirring. — Verre er det at på side 163 (som forøvrig Ramberg har gjort meg oppmerksom på) er de to reaksjoner

$$2LiCl + Cs_2CO_3 = Li_2CO_3 + 2CsCl$$

og

$$LiCl + KF = KCl + LiF$$

angitt med galt fortegn for ΔH. I virkeligheten representerer disse reaksjoner derfor intet bevis mot riktigheten av Rambergs prinsipp — at reaksjonen mellom saltpar er eksoterm i retning av dannelsen av salt av den sterkeste syre og det mest elektropositive metalls oksyd.

Men dessverre står ikke prinsippet sterkere av den grunn, av eksempler på uoverensstemmmelser er der fremdeles nok å velge mellom. Sammenlign:

$$Li_2SO_4 + Tl_2CO_3 = Li_2CO_3 + Tl_2SO_4$$
$$MgSO_4 + PbCO_3 = MgCO_3 + PbSO_4$$
$$Mg(NO_3)_2 + CoCO_3 = MgCO_3 + Co(NO_3)_2$$
$$Mg(NO_3)_2 + MnCO_3 = MgCO_3 + Mn(NO_3)_2$$

o.s.v. . . . . . som samtlige er eksoterme.

(Man kunne også tilføye:

$$NaCl + AgF = AgCl + NaF$$
$$BeS + FeO = BeO + FeS$$
$$MgS + FeO = MgO + FeS$$

o.s.v.)

Å betegne dette som «unntak», er lite treffende all den stund unntakene er likeså regelbundne som overensstemmelsene.

Kort og godt — prinsippet svikter, hvor det kommer på tvers av den fornuftige betraktningsmåte — ut fra ioneradier og polariserbarhet.

For sikkerhets skyld bør det kanskje også slåes fast at når elektronegativitetsskalaen viser seg uriktig å anvende på metallhalogenidenes affinitetsforhold, så blir grunnlaget bare ennå mere sviktende når det gjelder salter av oksysyrer. Her er jo ionekarakteren ennå mere utpreget.

H. Flood.

Elphidium clavatum CUSHMAN
from the Late-Glacial of Romerike, Norway

BY

ROLF W. FEYLING-HANSSEN.

A sample of the quick clay which caused the landslide of December 24th, 1953, at Borgen in Ullensaker, 30 km NE of Oslo, was collected by statsgeolog PER HOLMSEN on January 8th, 1954. A dry crust had then formed on the surface of the fluid quick clay which floated out by the landslide. The sample was taken 40 cm below the crust. The locality is situated about 160—170 m above sea-level (PER HOLMSEN).

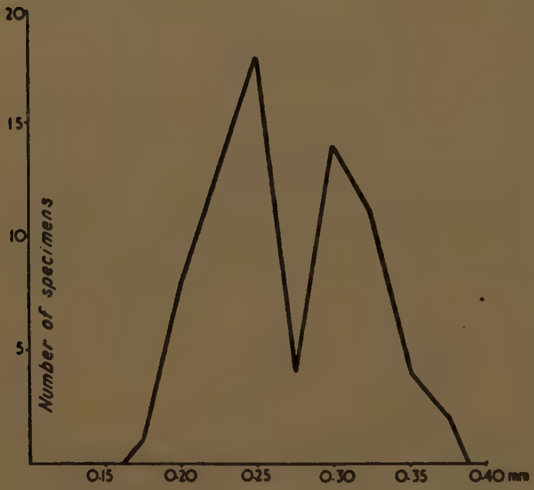


Fig. 1. Size distribution of 75 specimens of *Elphidium clavatum* from the Late-Glacial of Borgen in Ullensaker.

This sample was generously handed over to me for micropaleontological examination. It was poor in Foraminifera. 400 g of the sample (nr. 1144) contained:

134 specimens of *Elphidium clavatum* CUSHMAN, and 1 specimen *Globigerina* sp. (fragment).

Additionally many ostracod valves occurred and also one complete specimen, one valve and some fragments of the pelecypod *Yoldiella lenticula* (MØLLER) (= *Portlandia lenticula*). The complete specimen of this species had united valves.

According to its fossil content, the quick clay is assumed to be of Late-Glacial age.

The fragment of *Globigerina* sp. had an old and worn appearance, hence it was most probably redeposited. If so, the foraminiferal fauna *in situ* contained exclusively *Elphidium clavatum*.

In a sample from Jessheim (nr. 1105, mentioned in FEYLING-HANSSEN: Late-Pleistocene Foraminifera from the Oslofjord area. — Norsk Geol. Tidsskrift, Vol 33, p. 120, Oslo 1954) the Foraminifera was similarly represented only by *Elphidium clavatum*.

Dominant occurrence of this species was otherwise recorded from the *Yoldia*-clay (to the south of the Ra) and partly from the *Arca*-

clay, Late-Glacial of the Oslofjord area (Cf. above-mentioned paper).

The greatest diameter of 75 specimens of *E. clavatum*, from the quick clay of Borgen in Ullensaker, was measured. It varied from 0.17 mm to 0.38 mm. The size distribution is illustrated in fig. 1.

NY LITTERATUR

H. v. PHILIPSBORN: *Tafeln zum Bestimmen der Minerale nach aüsseren Kennzeichen.* XXVII + 244 sider, 289 krystalltegninger, 10 plansjer. Format 26.5 × 19 cm. Pris DM. 17. Stuttgart 1953 (E. NÄGELE).

Boken er dedisert til minnet etter J. A. WEISBACH (1833—1901) og F. KOLBECK (1860—1943), som var v. PHILIPSBORNS forgjengere som professorer ved Bergakademiet i Freiberg i Sachsen og hvis «Tabellen zur Bestimmung der Mineralien nach aüsseren Kennzeichen» har gått gjennom 13 opplag (det siste i 1923) og vil være velkjente for eldre norske bergingeniører.

v. PHILIPSBORNS tabeller representerer imidlertid et helt nytt verk — ideen fra de gamle WEISBACH - KOLBECKS tabeller er beholdt, men innholdet er helt nytt.

Foruten farve, strek, glans, habitus og aggregatform — hvoretter mineralene er ordnet — har v. PHILIPSBORN også inkludert som «ytre kjennetegn» mineralenes kjemiske og mikroskopisk-optiske egenskaper, og gir følgelig også tabeller over kjemiske reaksjoner og kjemiske sammensetninger, samt over optiske kjennetegn. Her er også oppført en del mineraler fra kjeramiske masser, ildfast sten, sementklinker, glass, og slagger. Ved kryssreferanser er det lett å finne det samme mineral i alle tabeller.

Den mikroskopisk-optiske del er noe ufullstendig, men forøvrig er boken utmerket. Den gir en mengde opplysninger og vil kanskje særlig være av betydning for geologer, bergingeniører og mineralsamlere som arbeider uten lett adgang til et geologisk bibliotek.

Tom. F. W. Barth.

Petrography. By HOWEL WILLIAMS, FRANCIS J. TURNER and CHARLES M. GILBERT. VII + 406 pages, 133 figures.

To teachers and students of geology I want to point out this unique book as an excellent aid in teaching and learning. The au-

thors state in the preface that the book is concerned with the description of rocks rather than with problems of genesis. As such it is an excellent textbook which is urgently needed in all universities. Obviously it has not been an easy book to write, there is nothing like it before; much of the information here presented, the student has had to rake together from widely scattered sources in hand-books and journals.

Part I: *Igneous Rocks*, by HOWEL WILLIAMS 160 pages. In the introduction just enough information is given about the theoretical background of rock formation (magmatic evolution, stages of consolidation of magma), to enable the author to refer to certain important petrogenic problems in the descriptive text. The following rock groups are described: The Gabbro Clan. The Alkali Gabbro Clan. The Ultramafic Clan and the Lamprophyres. The Diorite, Monzonite, and Syenite Clans. The Granodiorite, Adamellite, and Granite Clans. Pyroclastic Rocks.

Part II: *Metamorphic Rocks*, by F. J. TURNER, 90 pages, likewise opens with a theoretical chapter dealing with conditions controlling metamorphism, types of metamorphism, crystalloblastic growth, metamorphic facies, etc. giving a clear, concise background for the descriptions of the great varities of metamorphic rocks: Hornfelses and Spotted Slates. Cataclasites, Mylonites, and Phyllonites. Slates, Phyllites, and Schists of Low Metamorphic Grade. High-grade Schists, Amphibolites, Granulites, and Eclogites.

Part III: *Sedimentary Rocks*, by C. M. GILBERT, 133 pages. Again the same plan is adopted. Discussed are factors in the formation of sedimentary rocks, control of tectonic environment, stability of minerals, size, shape, sorting and packing of grains, etc. The description of the sediments is grouped under the following headings: Sandstones. Argillaceous Rocks. Calcareous Rocks. Miscellaneous Sedimentary Rocks.

The book has a short list of references, and a good index of both subjects and localities.

Tom. F. W. Barth.

V. M. GOLDSCHMIDT: *Geochemistry*. Edited by ALEX MUIR. Oxford 1954. XI + 730 pp. Pris 70 kr.

Ved Goldschmidts død i 1947 var manuskriptet til denne boken ikke fullført. Det var nedskrevet i Skottland og England under og etter krigen, til dels under vanskelige forhold. Ingen del av manuskriptet er skrevet senere enn 1946. Part II, som utgjør det meste av boken og handler om de enkelte elementers geokjemi, var i hoved-

saken ferdigskrevet, men 2 elementer manglet helt og 5 andre var ufullstendig behandlet. Til Part I, den generelle del, fantes bare spredte notater. Det var derfor et meget stort og krevende arbeid utgiveren dr. MUIR påtok seg. Foruten å redigere verket har han selv skrevet et av de manglende avsnitt (om selen) og for øvrig mange steder tilføyet nye data og resultater fra de siste år. Blant dr. MUIRS hjelpere i arbeidet må spesielt nevnes den nåværende leder av Statens råstofflaboratorium, ingeniør A. KVALHEIM. Dr. STURE LANDERGREN har på oppfordring skrevet det manglende avsnitt om fosfor.

Part I består for en del av oversettelser fra tidligere publikasjoner av Goldschmidt. Som dr. MUIR sier i forordet ville Goldschmidt utvilsomt ha modernisert Part I om han hadde levet nå. Men som den står gir den likevel et godt inntrykk av Goldschmidts generelle resultater og hans syn på geokjemien som helhet.

Part II sammenfatter Goldschmidts omfattende viten om de enkelte elementers geokjemi; den bygger i stor utstrekning på resultater fra hans egne laboratorier i Oslo og Göttingen. Det er overordentlig betydningsfullt at dette store materialet nå er tilgjengelig, og for Goldschmidts tidligere medarbeidere og elever er det spesielt gledelig, — de vil alle føle seg mer eller mindre «hjemme» i denne boken.

Stilen er typisk Goldschmidt; man tenker uvilkårlig tilbake på hans geokjemiske og mineralogiske forelesninger. Det hele er lettlest og greit, man kan nesten si det er underholdende lesning. Nettopp av denne grunn kunne man kanskje peke på rent formelle ufullkommenheter: Goldschmidt er ikke redd for gjentagelser når han synes de er på sin plass. Det er mulig at manuskriptet ikke var helt trykkferdig, og at slike detaljer ville blitt revidert ved en siste gjennomlesning. Men for leseren er denne «muntlige» stilen nærmest en fordel.

Geokjemikere og geologer er dr. MUIR stor takk skyldig for at han har gjort Goldschmidts siste verk tilgjengelig på en så utmerket måte. Bokens utstyr er meget godt.

Ivar Oftedal.

BRUHNS-RAMDOHR: *Kristallographie.* Sammlung Göschen Bd. 210, 106 s. DM 2.40. Walter de Gruyter & Co., Berlin 1954.

Denne siste utgaven av Göschen-seriens kjente krystallografi er kommet til redaksjonen fra forlaget. Ramdohrs navn er en garanti for at moderniseringen av boken er utført på en forsvarlig måte. Men om anlegget og stoffvalget kan meningene selvsagt være forskjellige. Problemet å få krystallgeometrien, krystallkjemien og krystallfysikken inn i et slikt lite hefte kan løses enten ved å framstille noen hovedtrekk for lesere uten krystallografiske og mineralogiske forkunnskaper, eller ved å gjøre boken til en sammentrengt «huskeliste» for lesere som allerede kjenner stoffet. Ramdohr synes nærmest å ha tatt sikte på det første. Men likevel inneholder boken spredt ut over det hele mange avsnitt og formuleringer som er så knappe og konsentrerte at de må være meget vanskelige å forstå for den uforberedte. Stort sett er de korrekte, men de forutsetter ofte ganske gode kunnskaper i kjemi, mineralogi, etc. Noen detaljer kan kritiseres, men de er ikke så viktige at det er grunn til å trekke dem fram her. Der er også en del trykkfeil, delvis av den art at den ukyndige leser ikke kan rette dem selv. — Boken er bare delvis egnet som en første innføring i krystallografien. Men for studerende kan den godt anbefales, særlig fordi den for en billig penge gir nyttige tabeller og figurer som ellers må søkes i større lærebøker.

Ivar Oftedal.

Edelsteine und Perlen. Av K. SCHLOSSMACHER. Stuttgart 1954. 280 sider. Ill. bl. a. 2 fargepl. Lerretsb. D M. 25,00. E. Schweizerbart'sche Verlagsbuchhandlung, Stuttgart.

Forfatteren, som tidligere har vært professor i mineralogi og petrografi ved Universitetet i Kønigsberg, er leder av «Staatl. Institut für Edelsteinforschung» i Idar-Oberstein. En rekke tillitshverv samt æresmedlemskap i tyske, engelske og amerikanske selskaper viser ytterligere at han er en fagmann av høyeste klasse. Tidligere har han utgitt et meget større verk; en fullstendig omarbeidet 3dje utgave av Max Bauers «Edelsteinkunde». Foreliggende bok, som er en mer lettfattelig erstatning for en 4de utgave, er beregnet på juvelerer, gullsmeder, edelstens-slipere osv.

«Edelsteine» er her gjort svært omfattende, idet perler, rav og koraller også tas med. Halv-edelstener er et begrep som forfatteren anbefaler skal forsvinne. Ord som ekte, edel, naturlig og virkelig skal etter almindelige avtaler nå bare brukes om natursten i forbindelse med sitt riktige navn. Vendinger som «Ekte Kaprubin» eller «Ekte syntetisk rubin» er altså da gale.

Den generelle del, ca. 80 sider, omhandler egenskaper og undersøkelsesmetoder. Det er gode redegjørelser bl. a. om «Farbe», «Farbmessung», «Farbveränderung», «Einschlüsse» osv.

I den spesielle del, ca. 160 sider, behandles edelstenene gruppevis etter vanlig mineralogisk prinsipp. Det gies for hvert mineral fyldige opplysninger om kjemiske og fysiske egenskaper, dannelse, lokaliteter, produksjon, verdi og noe historikk. Videre liknende mineraler, imitasjoner, syntetiske mineraler. Både produksjon og verdiangivelse er oftest ajour pr. sommeren 1953.

Den praktiske del omhandler slipeformene og slipning, gravering, handelsveier etc. Som tillegg er det tabeller over lysbrytningsindex, spess.vekt og hårdhet.

Ifølge forfatterens forord er boken ikke spesielt beregnet på geologer, men det er allikevel klart at en slik samling av opplysninger, hvorav en stor del kanskje ligger utenfor rammen av vanlige mineralogiske lærebøker, vil være til nytte for geologer. Et godt register gjør den også til en utmerket oppslagsbok.

J. A. Dons.

Norges geotekniske institutt,

som ble offisielt opprettet 1. januar 1953, sender i disse dager ut en serie på tre publikasjoner, hver med to eller tre artikler. Selv om disse artiklene har stått i innen- eller utenlandske fagtidsskrifter, er det meget hensiktsmessig at instituttet gir ut sine publikasjoner samlet her i landet. Det er mange mennesker i Norge som er interessert i spørsmål om byggegrunn eller leirfall, men det er sikkert meget få av dem som kommer over utenlandske spesialtidsskrift. Ganske særlig vil geologer, hvis arbeidsområde jo grenser til geoteknikernes, ha interesse av mange av artiklene.

Da alle artiklene er skrevet meget konsentrert og utstyrt med resymé, skulle det ikke være nødvendig med noe referat av dem her. Det får være nok å hilse den nye serien velkommen, og forøvrig henvise til fortegnelsen over publikasjonene.

Publikasjon 1:

O. Folkestad og L. Bjerrum: Norges geotekniske institutt.

O. Eide og L. Bjerrum: Geotekniske betraktninger over jords anvendelse som byggemateriale.

1953. Pris, kr. 4,00.

Publikasjon 2:

P. Holmsen: Landslips in Norwegian quick-clays.

I. Th. Rosenqvist: Considerations on the sensivity of Norwegian quick-clays.

1953. Pris, kr. 4,00.

Publikasjon 3:

L. Bjerrum: Les pieux de fondation en Norvège.

N. Janbu: Une analyse énergétique du battage des pieux à l'aide de paramètres sans dimension.

L. Bjerrum: Porenwasser-Spannungen beim Bau von Erddämmen.

1953. Pris, kr. 4,00.

Bergen, 6. mai 1954.

Niels-Henr. Kolderup.

NORSK GEOLOGISK FORENING

Møte 345 torsdag 5. mars 1953 på Farmasøytisk Institutt, Blindern.

Tilstede 25 medlemmer og 7 gjester.

Det ble meddelt at en vil søke å trykke foredragsreferat i tidsskriftet.

Spørsmålet om også å trykke diskusjonsinnlegg ble reist av Dietrichson.

Det ble meddelt at styret hadde mottatt fra redaksjonen i Bergen bind 31 og bind 32 hefte 1 av tidsskriftet.

Foredrag av *R. C. Sørbye* (*Bergen*): *Kaledonidene i nord-østre Ryfylke og på Haugesundshalvøya.*

På de eldre geologiske kart fra dette området, som stort sett dekkes av de topografiske gradteigkart Vikedal og Haugesund, finner vi tre atskilte bergartformasjoner: 1. Grunnfjell, 2. Fyllittavdeling, 3. Høyfjellsgneis. Denne tre-inndeling kan for oversiktens skyld ennå brukes, hvis vi istedenfor «grunnfjell» skriver «basalbergartene». Nyere undersøkelser på gradteig Haugesund viser nemlig en så kraftig påvirkning av den kaledonske orogenese i dette strøk, at sikre pre-kambriske bergarter ikke lenger kan finnes vest for grensen Nedstrand — Bjoestrand, altså i det område som kalles Haugalandet.

Min oppgave er å søke å påvise intensitetsgraden av den kaledonske orogenese i de tre bergartformasjoner fra Suldalshei til Bømlafjord.

Forholdene langs grensene mellom disse formasjonene samt metamorfosen i fyllittene eller glimmerskifrene har hittil gitt de beste bidrag til løsning av oppgaven.

I Suldalshei er grensen autokton, idet der er funnet udeformert basalkonglomerat, og de underliggende grunnfjellsbergartene er diskordant mot grensen. De tilnærmet horisontale kaledonske skyvninger har her foregått oppe i fyllittformasjonen, og grensen mellom fyllittavdelingen og høyfjellsgneisene er en tydelig skyvegrense.

I området mellom Saudafjord — Sandsfjord og Haugalandets basalkompleks har skyvningene også gått for seg langs denne grensen, og dermed gitt en konkordans på opptil et par meter i grunnfjellsbergartene umiddelbart under. Sen- eller postkaledonske, tilnærmet vertikale sprekker og forkastninger, tildels med breksiering, har dessuten forstyrret grenseforholdene, særlig langs den nord — syd-gående arm av Vindafjorden og mot Haugalandets basalkompleks. Denne siste grense er en tydelig sekundær skyvegrense.

Også i fyllittavdelingen, helt opp i de overliggende gneiser, har det foregått skyvninger, og i området nord for Vindafjorden har også andre kaledonske innflytelser gjort seg gjeldende. Her fås nemlig gradvise overganger mellom fyllitter og gneiser. Overgangsleddene er stort sett injeksjonsmetamorfe og må særlig skyldes tilførsel av Na-holdige løsninger fra gneisene over. Albittpegmatittganger er vanlig i de øvre fyllitter. I et område fås oligoklas-sillimanitt-staurolittgneis som endeledd i den metamorfe serie.

De fleste steder er de overliggende gneiser ikke annet enn metamorfe glimmerskiferprodukter. Bare i Hustveitsåtemassivet sørvest for Sauda finnes granittiske og syenittiske gneiser, som opp mot toppen går over i forholdsvis massive og friske Bergen-Jotunbergarter.

Det ser foreløpig ut til at metamorfosen i disse øvre lag av fyllittene er posttektonisk, dvs. at de overliggende gneiser, som trolig er kommet på plass ved skyvning, er blitt delvis rejuvenert da trykket lettet etter skyvningen.

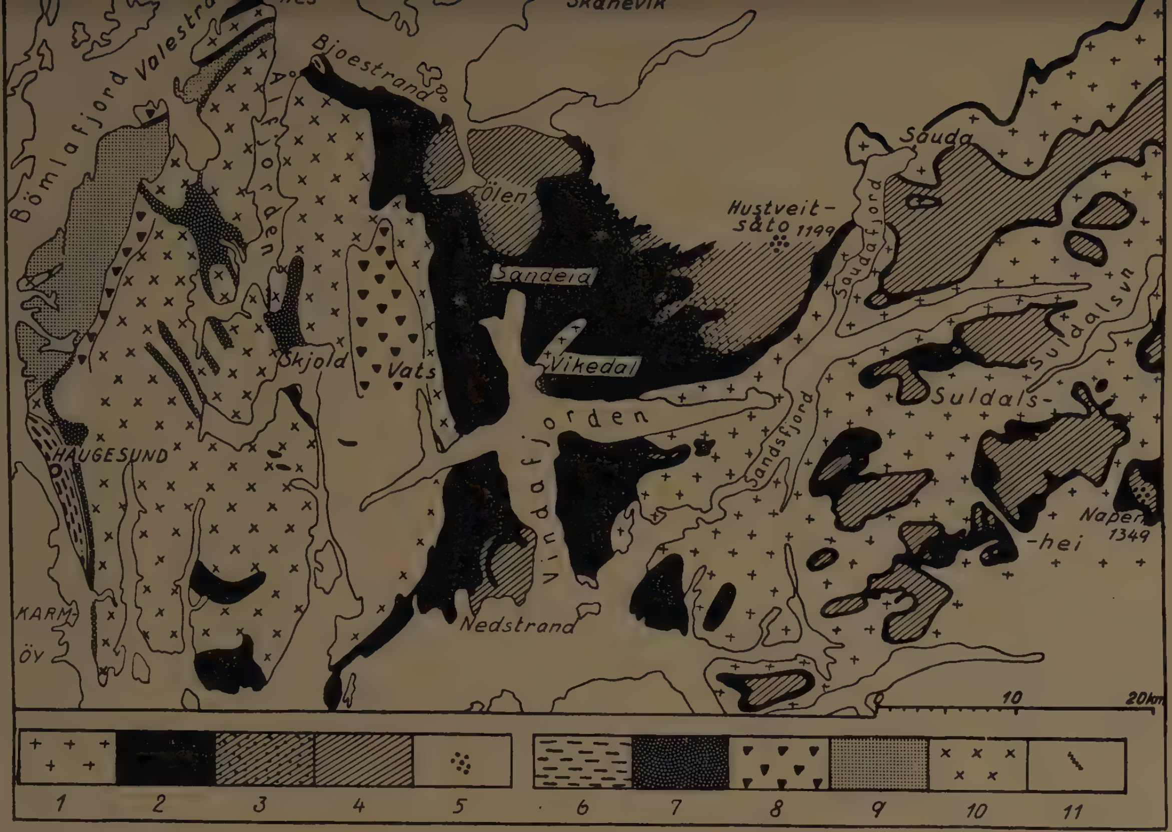
Langs grensene mot basalbergartene er fyllittene lavmetamorfe.

I Haugalandets basalkompleks finnes tre typer av glimmerskifre: 1. Overliggende, lavmetamorfe skifre, 2. Innfoldete, tildels metasomatisk omvandlete skifre, 3. Helt innesluttete, metasomatisk og tildels høymetamorf omvandlete glimmerskifre. De er alle trolig av kambro-silurisk opprinnelse. Omvandlingen i 3. har gått for seg i to trinn, idet den utpregete sillimanittdannelse antas å skyldes varmevirkninger fra de yngre granitter, og metasomatosen må skyldes senmagmatiske løsninger fra disse.

Både granitter og kvartsdioritter på den vestlige 2/3 av Haugalandet er yngre enn glimmerskifrene, og må følgelig være av kaledonsk alder. Hvor de har gjennomtrengt basiske bergarter fås utpregete migmatittstrøk, som øst for Haugesund og omkring midten av Ålfjord.

En diorittisk, tildels gabbroid bergartsone, som ser ut til å være yngre enn grønnskifrene, strekker seg fra Valestrand langs Bømlafjorden til nord for Haugesund. Den er trolig analog til gabbroene og diorittene på Bømlo og Karmøy, og må være kaledonsk. At den er eldre enn granittene og kvartsdiorittene er også trolig, men hittil ikke bevist.

Alle bergartene på Haugalandet, unntatt grønnskifrene og noen av granittene, gjennomsettes av pegmatittganger som vesentlig hører



Geologisk oversiktskart over NÖ Ryfylke og Haugesundshalvøya.

1. Grunnfjellsgranitt og kvartsdioritt. 2. Fyllitt. 3. Metamorf glimmerskifer. 4. Overliggende gneiser («høyfjellsgneiser»). 5. Massive Bergen-Jotunbergarter. 6. Grønnstein. 7. Metamorf glimmerskifer. 8. Hornblendeskifer, amfibolitt og glimmergneis. 9. Dioritt. 10. Granitt, kvartsdioritt, migmatitt. 11. Breksje.

til kvarts-feltspat-glimmer-typen med leilighetsvis granat. Bare noen få ganger, som dem i Vats, har andre mineraler i nevneverdig mengde. Thors grube med uranbekerts hører til disse.

Pegmatittgangene har på de fleste steder forårsaket kalimetasomatose og i enkelte tilfelle turmalindannelse i bergartene omkring.

I grønnskifrene ved Haugesund er trondhjemittiske ganger dominerende.

Til en senere fase hører de hydrotermale kis- og tildels også gullførende kvartsganger som finnes langs sen- eller postkaledonske sprekker. I en senkaledonsk breksje ved Bømlafjord (Eltravåg) opptrer flusspat som en del av bindemidlet.

Av samme alder, eller yngre enn sprekkene og kvartsgangene, er noen omvandlete diabasganger nordvest på Haugalandet.

Uten tvil må hele det opprinnelige pre-kambriske underlaget på Haugesundshalvøya ha vært dukket så langt ned i den kaledonske foldesone, at det foruten å få den kaledonske struktur, også for største delen ble rejuvenert, tildels med dannelse av helt nye eruptiver, og med mer og mindre gjennomgripende metamorfose av de eldre bergartstyper.

Konklusjonen kan også uttrykkes slik at den kaledonske synklinal rykker så langt inn på fastlandet at den derved også omfatter mesteparten av Haugalandets basalkompleks. *Intensiteten av den kaledonske orogeneses påvirkning av bergartene på Haugesundshalvøya og i nordøstre Ryfylke blir dermed gradvis sterkere og mer gjennomgripende vestover fra Suldalshei til Bømlafjord.*

(R. C. Sörbye: Geological Studies in the North-Eastern Part of the Haugesund Peninsula, Western Norway. Univ. i Bergen, Årbok 1948.
— Bergen-Jotunbergarter i fjellet Napen, Suldalshei. Univ. i Bergen, Årbok 1950).

I ordskiftet etter foredraget deltok: O. Holtedahl, B. Dietrichson, T. Strand, I. Th. Rosenqvist, P. Holmsen, K. Landmark og foredragsholderen.

Møte 346 torsdag 23. april 1953 i Drammensv. 78, Oslo.

Tilstede 26 medlemmer og 46 gjester.

Det ble meddelt at foreningen hadde søkt Kirke- og Undervisningsdepartementet om økonomisk støtte for arbeidet med å få i stand en internasjonal metamorfosekongress et av de kommende år.

Der ble videre referert en anmodning fra International Association of Hydrogeologists om å oppnevne en kontaktmann i Norge. Per Holmsen sa seg villig til å påta seg vervet.

Følgende nye medlemmer ble godkjent.

368. Statsgeolog dr. *Oskar Kulling*., S. G. U., Stockholm 50, foreslått av Chr. Oftedahl og T. Strand.

369. Preparant *Anker Iversen*, Geologisk Institutt, N. T. H., Trondheim, foreslått av Fr. Huseby og P. Holmsen.

370. Cand. real. *Ørnulf Logn*, Geologisk Institutt, N. T. H., Trondheim, foreslått av Fr. Huseby og P. Holmsen.

371. Prof. *K. Krauskopf*, p. t. Min. Geol. Museum, Oslo, foreslått av T. F. W. Barth og H. Neumann.

Foredrag av *Per Holmsen:* «Om norske bergarters hydrogeologi»,

og av *Steinar Skjeseth:* «Vann og vannboring i Hedemark og Oppland».

I ordskiftet etter foredraget deltok: G. Holmsen, Buster Sund, I. Th. Rosenqvist, A. L. Rosenlund, H. Tullstrøm, B. Dietrichson, Alf Berger, H. Major og foredragsholderne.

Holmsens foredrag er trykt i Kommunalt Tidsskrift nr. 9, 1953 og Skjeseths i N. G. U. Årbok for 1953.

Møte 347 torsdag 22. oktober 1953, Geografisk institutt, Blindern.

Fellesmøte for Norsk Geologisk Forening og Geografisk Assosiasjon.

Foredrag av professor *Richard J. Lougee* (Clark University, Worcester, Mass.):

A Chronology of Post-Glacial Time in Eastern North America.

I diskusjonen etter foredraget deltok: F. Isachsen, O. Holtedahl, H. Rosendahl og foredragsholderen.

Emnet er behandlet i foredragsholderens publikasjon av samme tittel i the Scientific Monthly, vol. LXXVI, no. 5, 1953.

Møte 348 torsdag 5. nov. 1953 i Drammensvegen 78, Oslo.

Tilstede 24 medlemmer og 6 gjester.

Forsamlingen mintes direktør Worm Hirsch Lund's bortgang.

Det ble referert skriv fra Pontius Ljunggren ang. Nordisk geologmøte i Gøteborg januar 1954.

Følgende nye medlemmer ble godkjent:

372. Dr. *Olof H. Ødman*, Sverige, foreslått av T. F. W. Barth og H. Neumann.

373. Ing. *Anders Sahlin*, Paleontologiska Institutionen, Uppsala, foreslått av N.-H. Kolderup og A. Kvale.

374. Cand. real *Sverre Svinndal*, Oslo foreslått av H. Neumann og L. Størmer.

375. Fil. mag. *Sigurd Holmberg*, Lervägen 24, Lund, foreslått av Sven Hjelmqvist og G. Regnell.

376. Dr. *Brian H. Mason*, The American Museum of Natural History, New York 24, New York, foreslått av T. F. W. Barth og H. Neumann.

377. Amanuensis cand. real. *Just Gjessing*, Geografisk institutt, Oslo, foreslått av K. Strøm og O. Holtedahl.

Foredrag av statsgeolog dr. *Chr. Oftedahl:*

«Dekketektonikken i den nordlige del av det østlandske sparagmittområde».

I ordskiftet etter foredraget deltok: P. Holmsen, B. Dietrichson, O. Holtedahl og foredragsholderen. Foredraget vil bli trykt i N. G. U. Årbok for 1953.

Møte 349 torsdag 26. nov. 1953 i Drammensvegen 78, Oslo.

Tilstede 16 medlemmer og 6 gjester.

Foredrag av prof. *T. F. W. Barth:*

«Den geologiske oppbygning av Pribiloføene i Beringhavet». I ordskiftet etter foredraget deltok Chr. Oftedahl, F. Isachsen, G. Liestøl, H. Rosendahl, T. Winsnes, O. Liestøl, N. Spjeldnæs, R. Feyling-Hanssen og foredragsholderen.

Prof. T. F. W. Barth's avhandling om Pribiloføenes geologi vil bli trykt i U. S. Geological Survey, Bulletin.

Møte 350 torsdag 10. desember 1953 i Drammensvegen 78, Oslo.

Tilstede 24 medlemmer og 11 gjester.

Referat fra den 4. internasjonale kvartærgeologiske kongress i Italia 1953 ved konservator *H. Rosendahl.*

Foredrag av universitetsstipendiat *R. W. Feyling-Hanssen:* «Noen alminnelige foraminiferer fra Oslofeltets kvartær».

Foredrag av konservator *H. Rosendahl:* «Forsøk på en strandlinje-kronologi».

I ordskiftet etter foredraget deltok O. Holtedahl, M. Marthiniussen, P. Holmsen og H. Rosendahl.

R. W. Feyling-Hanssens foredrag er trykt i N. G. T., Bd. 33, h. 1—2: Late-Pleistocene Foraminifera from the Oslofjord Area, Southeast Norway.

Årsmelding fra Bergens Geologiske Klubb 1953.

Bergens Geologiske Klubb har i 1953 hatt 6 foredragsmøter med gjennomsnittlig 17 tilhørere.

Følgende foredrag har vært holdt:

17/2: *Ruth C. Sørbye:* Om Haugesundshalvøyas geologi.
11/3: *Harald Major*, Norsk Polarinstitutt: Om kullforekomstene på Svalbard.
18/3: *Hans Holtedahl:* Noen submarine undersøkelser utenfor Norges vestkyst.
April: *Anders Kvale:* Stående bølger i vann i Norge og England i forbindelse med Assamjordskjelvet.
11/11: *Hans Holtedahl:* Forsøk med en ny bunnprøvetaker i Sognefjorden og Fjærlandsfjorden.
N.-H. Kolderup: Litt om gneisene i Sunnfjord.
21/11: Julemøte.
Olaf Holtedahl: Litt omkring den nye «Norges Geologi». Etter foredraget fest med ektefeller på Geologisk institutt.

Styret blir i 1954: Formann, dosent Anders Kvale.
Viseformann, lektor A. Samuelsen.
Sekretær, amanuensis Ivar Hernes.

GEOLOGNYTT

Norges Geologiske Undersøkelse.

Cand. real. *Kari Egede Larsen* ble 1. juli 1953 ansatt som vitenskapelig assistent.

Bergingeniør *Brynjulf Dietrichson* ble 1. juli 1954 ansatt som vikar i statsgeologstilling til 1. mars 1955.

Frank M. Vokes M.Sc. ble 10. mai 1953 ansatt midlertidig som bergingeniør og geolog.

Statsgeolog *Olaf Anton Broch* har fått forlenget permisjon til 1. mars 1955, mens han er midlertidig professor i mineralogi ved Universitetet i Punjab, Pakistan.

Statsgeolog *Johannes Færden* er innvilget permisjon i ett år fra 1. april 1954 for å utføre oppdrag for A/S Norsk Bergverk og Fosdalen bergverksaktiebolag.

Universitet i Oslo.

Førstekonservator *Henrich Neumann*, underbestyrer ved Mineralogisk-Geologisk Museum, har i høstsemestret 1953 vært associate professor i mineralogi ved University of Indiana.

I professor *Tom. F. W. Barths* forskningstermin, som begynner høsten 1954, skal dr. *Neumann* fungere som bestyrer av Mineralogisk-Geologisk Museum.

Følgende to Fulbright-stipendiater har arbeidet ved museet i studieåret 1953—54: *Charles M. Shaw*, California, og *John C. Green*, Connecticut.

Belgisk statsstipendiat *J. Michot* har likeledes vært gjestende forsker i samme tidsrom.

Dr. *Gunnar Kullerud*, som i flere år har arbeidet ved Geologisk Museum i Silikatlaboratoriet (Norges Almenvitenskapelige Forskningsråd), reiste i mars 1954 til U.S.A. for minst 2 års studier.

Vitenskapelig assistent ved Geologisk Institutt, *Bjørn G. Andersen*, oppholder seg med amerikansk stipendium ved Yale University, New Haven, Conn. *Håkon Ø. Lien* er ansatt som vikar til 1. juli 1955.

Professor dr. *Olaf Holtedahl* er innvalgt som korresponderende medlem av Société Géologique de Belgique. Han er i vår også blitt utnevnt til æresmedlem av Det Norske Geografiske Selskab.

Professor dr. *W. Werenskiold* er likeledes utnevnt til æresmedlem av Det Norske Geografiske Selskab.

Matematisk-naturvitenskapelig embetseksamen med mineralogi-petrografi som hovefag er i februar 1954 fullført av *Thor Siggerud jr.* Avhandling: «Geologien på en del av kartbladet Lifjell».

OLAF HOLTEDAHL: «*Vår forundelige klode. Fra friluftsliv og forskningsferder*». (Aschehoug) er utkommet i hollandsk oversettelse: «*De Aarde en haar Wonderen*». (L. J. Veen, Amsterdam).

Det er av tippe-midler nylig bevilget et beløp på kr. 950.000,00 til påbegynnelse av nybygg for de geologiske institutter på Blindern (Mineralogisk inst., Geologisk inst. og Paleontologisk inst.).

Universitetet i Bergen.

Konservator I *Hans Holtedahl* ved Geolologisk institutt ble 1. juli 1953 ansatt som førstekonservator samme sted.

Cand. real. *Ivar Hernes* ble 1. juli 1953 fast ansatt i stillingen som amanuensis I ved Geologisk institutt.

Cand. mag. *Natascha Heintz* er ansatt som museumsstipendiat med plikt til å arbeide vårsemestret 1954 ved Geologisk institutt.

Professor dr. *N.-H. Kolderup* var representant for Norsk Geologisk Forening ved VI. Nordiske geologmøte i Finnland i mai 1954.

Norges Tekniske Høgskole.

Dosent dr. *Jens A. W. Bugge* ved Geolologisk institutt ble 1. april 1954 utnevnt til professor i malmgeologi.

Cand. real. *Fredrik Chr. A. Huseby* ble 1. juli 1953 ansatt som vitenskapelig assistent.

Tromsø Museum.

Stud. real. *Natascha Heintz* var i høstsemestret 1953 ansatt som museumsstipendiat med plikt til å arbeide ved Geologisk avdeling.

MEDLEMSLISTE

à jour januar 1954.
[1]: korresponderende medlem.
*: livsvarig medlem.
Tallet i parentes er innvalgsåret.
(S): stifter (18. februar 1905).

*Adamson, Olge J., dr. Frantsebråtveien 3, Vækerø, Oslo. (1945).
Ahlmann, Hans W:son, ambassadør. Kgl. svenske ambassade, Meltzer's gate 4. Oslo. (1919).
Alsgaard, P., overingeniør. Herøya pr. Porsgrunn. (1945).
Andersen, Bjørn, assistent. Geologisk institutt, Blindern, Oslo. (1952).
Andersen, S. A., dr. Studiestrædet 3, København. (1947).
Asklund, Bror, statsgeolog. Sveriges Geologiska Undersökning, Stockholm 50. (1938).
*Bache, Laura, lektor. Eiksbo, vei 509, Eiksmarka. Røa, Oslo. (1931).
*Backlund, Helge, professor. Mineralogisk-geologiska Institutionen, Uppsala 1. (1919).
Baker, Donald, B. Sc. Dept. of Geology, Princeton University, Princeton, N. J., U.S.A. (1951).
*Balk, Robert, professor. Box 162, Campus Station, Cororro, N. M., U.S.A. (1933).
*Barth, Tom. F. W., professor. Geologisk museum, Oslo 45. (1921).
Bergersen, Birger, statsråd. Anton Schjøthsgt. 13, Oslo.
Bertheau-Hansen, Chr., bergingeniør. Norges geologiske undersøkelse, Oslo 27. (1942).
Birkeland, Tor, lektor. Avaldsnesgt. 36, Stavanger. (1946).
Bjerrum, Lauritz, direktør. Norges geotekniske institutt, Blindern, Oslo. (1952.)
*Bjørlykke, Harald, dr. Norsk Bergverk, Christian August's gate 15, Oslo. (1923).
Boughton, Eric. Hay Tor, 921 Harrow Rd., Wembly, Middlesex, England. (1932).
*Broch, Olaf Anton, professor. Dept. of Mineralogy, University of Punjab, Lahore, Pakistan. (1920).
Bruun, B., ingeniør. Geologisk museum, Oslo 45. (1938).
*Braastad, Johan, dr. Postboks 808, Oslo. (1913).
Bugge, Arne, dr. Utsiktsveien 21, Stabekk. (1914).
*Bugge, Carl, direktør. Håkon den gode's vei 12, Vindern, Oslo. (S).

*Bugge, Jens, dosent. Norges tekniske høgskole, Trondheim. (1940).

*Bulman, O. M. B., dr. Sedgwick Museum, Cambridge, England. (1951).

*Callisen, Karen, dr. Mineralogisk og Geologisk Museum, Østervoldgade 7, København K. (1917).

Carlson, Fredrik, overingeniør. Sandelsgatan 35, Stockholm. (1919).

*Carstens, Harald, geolog. Saxenborg, Trondheim. (1949).

Caster, Kenneth, professor. Dept. of Geology and Geography, University of Cincinnati, Cincinnati, Ohio, U.S.A. (1953).

*Chapman, Charleton A., professor. University of Illinois, Urbana. Ill. U.S.A. (1949).

*Chen Kwan Yuan, B. Sc. Geological Institute, National Peking University, Peking, Kina. (1951).

Collini, Bengt, fil. lic. Mineralogisk-geologiska Institutionen, Uppsala, Sverige. (1949).

Craig, H. B., dr. Dept. of Geology, University, Chicago 37, Ill., U.S.A. (1949).

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2 korresponderende medlemmer.
104 livsvarige medlemmer.
111 årsbetalende medlemmer.

217 medlemmer.